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# Airflow Traverse Comparisons Using The Equal-Area Method, Log-Tchebycheff Method, and The Log-Linear Method and Including Traverse Location Qualification

By

Eric M. Banks
Christopher S. Ellis
Curtis E. Graves

NUCON International, Inc
Columbus, Ohio

## Abstract

Air side flow measurement is normally accomplished in an air distribution system by first establishing the fan performance per AMCA-203. Ducted airflow measurements are typically determined utilizing the Pitot traverse measurement technique. The Pitot traverse measures flowing air velocity pressures and static pressures across a traverse plane in a duct location where airflow is as close to uniform flow as possible. The Pitot traverse readings are tabulated and air density is determined. The Pitot traverse data is utilized to determine the average velocity of the airflow. The density is determined to convert the airflow to standard volumetric airflow in SCFM or actual conditions in ACFM.

In cases where traverse readings cannot be obtained, anemometers can be utilized to measure the air velocity at terminal locations.

## Pitot Tube Traverse Methods

The volumetric flow rate through a cross-sectional area of ducting can be determined by measuring the local velocities at a sufficient number of points to establish the average velocity at the traverse location. The flowrate is calculated by taking the average of all velocity readings at predetermined traverse points (dependent on the method), and multiplying this average by the cross-sectional area of the duct. As a rule, based on the equal area rectangular duct method, the traverse should consist of a minimum of 16 readings but need not be more then 64 readings. The minimum and maximum number of readings are different for the other two methods referenced in this document.

The location of the traverse in a duct is very important. Airflow should be fully developed and uniform at the traverse location, with the only exception being lower velocities nearer to the duct edge. As a minimum, the traverse location should be at least eight duct diameters (larger of the two values for rectangular ducts when the two sides are not equal) downstream of any disturbances, and a minimum of two diameters upstream of any disturbances.

Currently, there are three methods for determining the layout of a traverse, **equal area, log-linear, and log -Tchebycheff** (original spelling is Chebyshev -- pronounced che-bu-chef or che-be-shev). Sections 1.1.1.1 through 1.1.1.3 provide illustrations of the three methods. These methods are also used to determine the location of the test ports to be installed in the ducting.

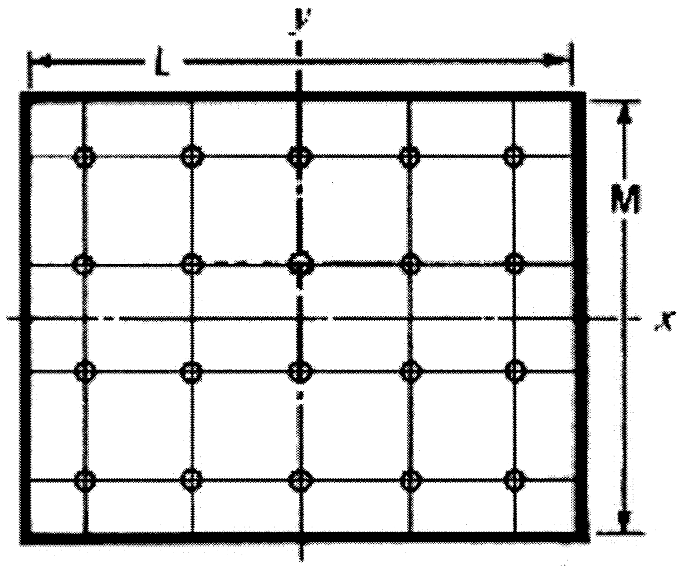
All three methods will return almost identical results for round ducts. However, substantial differences between the log-linear and the log-Tchebycheff method can exist when compared to the equal area method results for rectangular ducts. This is due in part to the equal area method not taking into account the lower velocities near the duct wall. In most cases, a positive error nearly always results when the equal area method is used.

- **Equal Area Method**

The most common method used in the United States is the equal area method. For a rectangular duct, this method divides the traverse plane into equal areas with the centers of each area no greater then six inches from the center of an adjacent area. The exception to this is in very large ducts where the total number of velocity readings would exceed 64. Under these circumstances, the distance between points may be greater than six inches. This method does not take into account the reduced airflow at the perimeter of the duct, thus each velocity reading is given equal weight in the averaging process.

The equal area method can also be applied for round ducts. It divides the cross-sectional area of the traverse plane into equal area "doughnuts". Typically, two traverse planes are established with each being 90° apart from one another. The distance between each velocity measurement point increases as the traverse progresses from the edge of the duct (lower velocity) toward the center of the duct (higher velocity). Conversely, the distance between points decreases as the traverse passes the center of the duct and progresses to the opposite edge of the duct. No velocity readings are taken in the center of the duct.
The minimum number of readings can be 12 for very small ducts or up to 40 for very large ducts. Ducts that are eight inches in diameter or smaller should use 12 points; ducts between 8 and 12 inches should use 16 points, and ducts larger then 12 inches should use either 20 or 40 points total. For ducts smaller then 12 inches, a micro Pitot tube should be used. In all cases, each velocity reading is given equal weight in the averaging process.

To determine the number of points that the Pitot tube is to be positioned inside the duct or where the test ports are to be located on the duct, take either **L (x)** axis or the **M (y)** axis, in inches, and divide by six. If this number has a remainder then it is rounded up to the next higher integer with no remainder. This is the minimum number of points to be used.




| Number of Points | Distance From The Edge Of The Duct (Multiply the duct dimension that the Pitot tube is to traverse across by the numbers below, based on the points per test port. This distance is how far the Pitot tube will be from the edge of the duct for each point.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 4 | 0.125 | 0.375 | 0.625 | 0.875 | | | | |
| 5 | 0.100 | 0.300 | 0.500 | 0.700 | 0.900 | | | |
| 6 | 0.083 | 0.250 | 0.417 | 0.583 | 0.750 | 0.917 | | |
| 7 | 0.071 | 0.214 | 0.357 | 0.500 | 0.643 | 0.786 | 0.929 | |
| 8 | 0.063 | 0.188 | 0.313 | 0.438 | 0.563 | 0.688 | 0.813 | 0.938 |

**Figure 1-1: Equal Area Method for a Rectangular Duct**

Example:

Assume that a duct has a dimension of 19” in the **M (y)** axis and 30” in the **L (x)** axis.

To calculate the minimum numbers of points that the Pitot tube is to be positioned inside the duct when traversing the 19” **(M)** axis perform the following:

**N = M(y) / 6**
**N = 19 / 6 = 3.17** this is rounded up to 4

This means the minimum number of points that the Pitot tube will be positioned at is four.

Using the mathematical method:

Pitot Position 1 (PP1): **(M/N)**/2 = (19/4) / 2 = 2.375" from the edge of the duct.
Pitot Position 2: **M/N** + PP1 = 19 / 4 + 2.375 = 7.125" from the edge of the duct.
Pitot Position 3: **M/N** + PP2 = 19 / 4 + 7.125 = 11.875" from the edge of the duct.
Pitot Position 4: **M/N** + PP3 = 19 / 4 + 11.875 = 16.625" from the edge of the duct.

Using Figure 1-1:

Pitot Position 1: 19 X 0.125 = 2.375" from the edge of the duct.
Pitot Position 2: 19 X 0.375 = 7.125" from the edge of the duct.
Pitot Position 3: 19 X 0.625 = 11.875" from the edge of the duct.
Pitot Position 4: 19 X 0.875 = 16.625" from the edge of the duct.

The test ports are located on the 30"**(L)** side. To calculate the position of the test ports that will need to be installed on the duct, perform the following:

Total number of test ports to be installed.

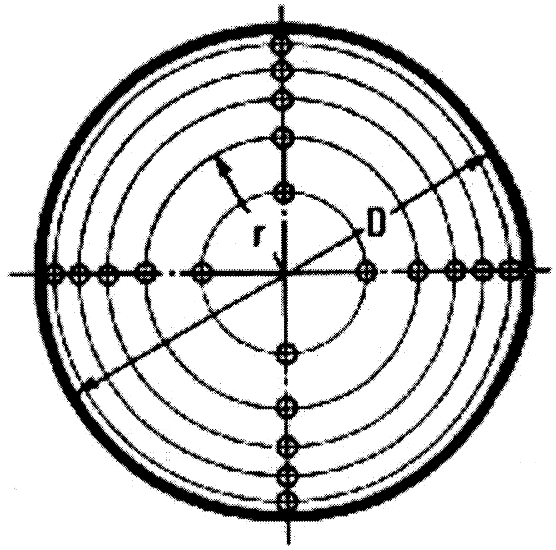
**30/6 = 5.0** This is the minimum number of test ports that will need to be installed.

Using the mathematical method:

Test Port Position 1: **(L/N)**/2 = (30/5) / 2 = 3.0" from the edge of the duct.
Test Port Position 2: **(L/N)** + TTP1 = (30/5) + 3.0 = 9.0" from the edge of the duct.
Test Port Position 3: **(L/N)** + TTP2 = (30/5) + 9.0 = 15.0" from the edge of the duct.
Test Port Position 4: **(L/N)** + TTP3 = (30/5) + 15.0 = 21.0" from the edge of the duct.
Test Port Position 5: **(L/N)** + TTP4 = (30/5) + 21.0 = 27.0" from the edge of the duct.

Position of each test port with regards to the edge of the duct using Figure 1-1:

Test Port Position 1: 30 X 0.10 = 3.0" from the edge of the duct.
Test Port Position 2: 30 X 0.30 = 9.0" from the edge of the duct.
Test Port Position 3: 30 X 0.50 = 15.0" from the edge of the duct.
Test Port Position 4: 30 X 0.70 = 21.0" from the edge of the duct.
Test Port Position 5: 30 X 0.90 = 27.0" from the edge of the duct.




Two diameters are shown, with each diameter having ten points.

| PTS. Per DIA | Distance From The Edge Of The Duct (Multiply the duct diameter by the number below) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| **1 thru 6** | 0.043 | 0.146 | 0.296 | 0.704 | 0.854 | 0.957 | | | | |
| **1 thru 8** | 0.032 | 0.105 | 0.194 | 0.323 | 0.677 | 0.806 | 0.895 | 0.968 | | |
| **1 thru 10** | 0.026 | 0.082 | 0.146 | 0.226 | 0.342 | 0.658 | 0.774 | 0.854 | 0.918 | 0.974 |
| **1 thru 20** | **1&11** | **2&12** | **3&13** | **4&14** | **5&15** | **6&16** | **7&17** | **8&18** | **9&19** | **10&20** |
| **1-10** | 0.013 | 0.039 | 0.067 | 0.097 | 0.129 | 0.165 | 0.204 | 0.250 | 0.306 | 0.388 |
| **11-20** | 0.612 | 0.694 | 0.750 | 0.796 | 0.835 | 0.871 | 0.903 | 0.933 | 0.961 | 0.987 |

## Figure 1-2: Equal Area Method for a Round Duct

Example:

Assume a round duct has a diameter of 18”. Using Figure 1-2, calculate the Pitot tube position in each plane:

Pitot Position 1: 18 X 0.026 = 0.47” from the edge of the duct.
Pitot Position 2: 18 X 0.082 = 1.48” from the edge of the duct.
Pitot Position 3: 18 X 0.146 = 2.63” from the edge of the duct.
Pitot Position 4: 18 X 0.226 = 4.07” from the edge of the duct.
Pitot Position 5: 18 X 0.342 = 6.16” from the edge of the duct.
Pitot Position 6: 18 X 0.658 = 11.84” from the edge of the duct.
Pitot Position 7: 18 X 0.774 = 13.93” from the edge of the duct.
Pitot Position 8: 18 X 0.854 = 15.37” from the edge of the duct.
Pitot Position 9: 18 X 0.918 = 16.52” from the edge of the duct.
Pitot Position 10: 18 X 0.974 = 17.53” from the edge of the duct.

- **Log Linear Method**

The second method is known as the log-linear method and is based on the Nikuradse (pronounced nee-coor-ood-zuh) formula for fully developed flow. This is not a common method and is more complex than the other two methods. Each velocity measurement point is based on a logarithmic distribution in one plane. The Pitot tube position for each test port location uses a logarithmic value. This method is further complicated by the weighting values applied to each velocity reading for a rectangular duct, as opposed to a round duct, where all velocity readings are weighted equally. For a rectangular duct, each velocity reading is multiplied by a weighting value (e.g.2/96, 3/96, 5/96, or 6/96) then all of these weighted values are added together to arrive at the average air velocity.

This method differs from the equal area for a round duct in that it uses three test port penetrations that are 60° apart as opposed to the two duct penetrations that are 90° apart. The following pictures and tables better describe this method. The minimum number of points for a rectangular duct is 26, and can be anywhere from 18 to 30 for a round duct.

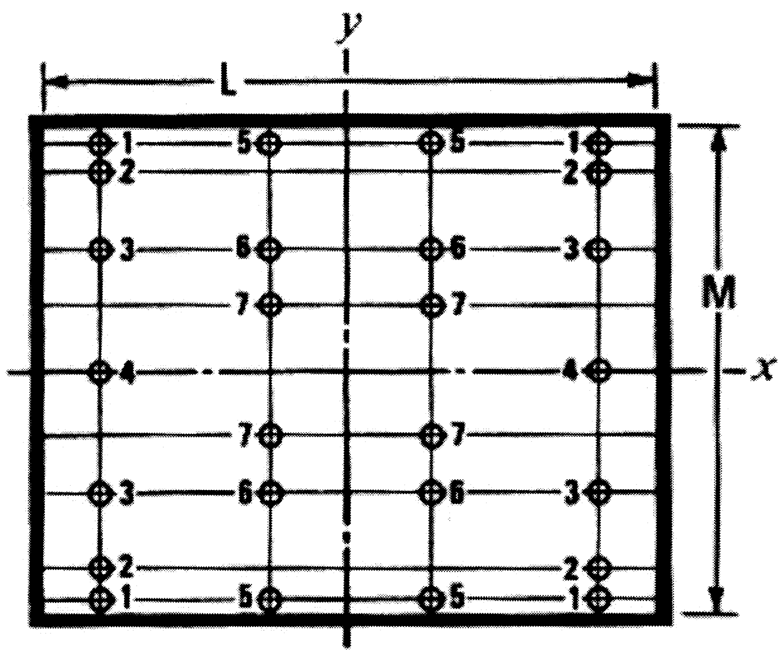
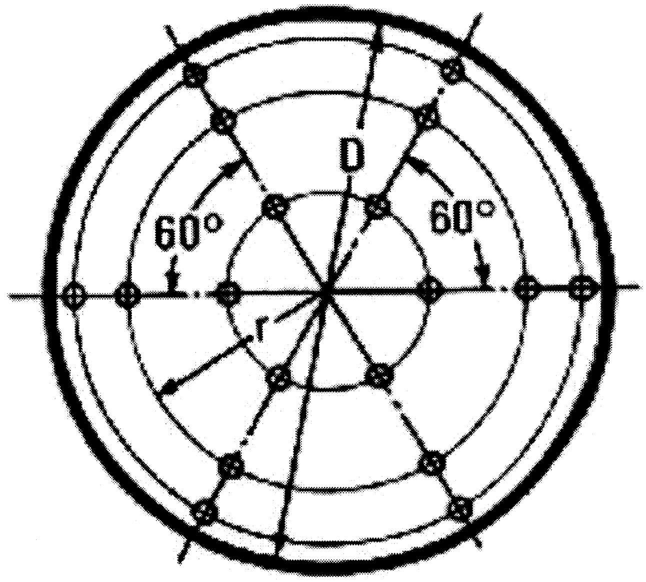



**Figure 1-3: Log Linear Method for a Rectangular Duct**

Twenty-six total points are shown.

| Point Number | Distance From The Center Of The Duct – (x or L) OR (y or M) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| X or L | ±0.408 | ±0.408 | ±0.408 | ±0.408 | ±0.132 | ±0.132 | ±0.132 |
| Y or M | ±0.466 | ±0.408 | ±0.250 | 0 | ±0.466 | ±0.250 | ±0.132 |
| F | 2/96 | 2/96 | 5/96 | 6/96 | 3/96 | 3/96 | 6/96 |




Three diameters are shown, with each diameter having six points

| PTS. Per DIA | Distance From The Edge Of The Duct (Multiply the duct diameter by the number below) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 6 | 0.032 | 0.135 | 0.321 | 0.679 | 0.865 | 0.968 | | | | |
| 8 | 0.021 | 0.117 | 0.184 | 0.345 | 0.655 | 0.816 | 0.883 | 0.979 | | |
| 10 | 0.019 | 0.077 | 0.153 | 0.217 | 0.362 | 0.638 | 0.783 | 0.847 | 0.923 | 0.981 |

## Figure 1-4: Log Linear Method for a Round Duct

Example:
Assume a rectangular duct that has a dimension of 17" X 17" and that there is a transition to a round duct with a diameter of 18". For the rectangular duct, the test ports are to be added to the bottom of the duct. Referring to Figure 1-3 this would be along the **L (x)** axis. Test ports need to be installed at the one and five positions relative to the duct centerline.

Test Port Position 1(1): 17 X 0.408 = 6.94" away from the center of the duct.

Because it is not always practical to mark the duct using the center as the reference point, it would be more practical if the edge of the duct were used. Because the center of the duct is 8.5" from the edge of the duct, subtracting 6.94 from 8.5 will give the location relative to the edge of the duct.

Test Port Position 1(1): 8.5 - 6.94 = 1.56" from the edge of the duct.

Perform the same operation to determine the position of the second test port (number 5 on Figure 1-3)

Test Port Position 2(5): 17 X 0.132 = 2.24" from the center of the duct.
Test Port Position 2(5): 8.5 – 2.24 = 6.26" from the edge of the duct.

Once the duct center has been reached the 8.5 will now be additive and not subtractive.

Test Port Position 3(5): 17 X 0.132 = 2.24" from the center of the duct.
Test Port Position 3(5): 8.5 + 2.24 = 10.74" from the edge of the duct.

Test Port Position 4(1): 17 X 0.408 = 6.94" from the center of the duct.
Test Port Position 4(1): 8.5 + 6.94 = 15.44" from the edge of the duct.

After the test port position has been determined, the ports would be drilled out and test port covers installed. The next step will be to determine the Pitot tube position at each duct test port penetration.

Referring to Figure 1-3, it is determined that the Pitot tube will traverse along the **M (y)** axis. Test ports one and four will have the same Pitot tube spacing but are different than test ports two and three, which are also the same. Likewise, test ports one and two, and three and four have several Pitot positions that are the same. These are position one and five, and three and six. To calculate Pitot positions 1, 2, 3, and 4 below the center of the duct, for test ports 1 and 4 perform the following:

Pitot Position 1: 17 X 0.466 = 7.92" from the center of the duct.
Pitot Position 1: 8.5 – 7.92 = 0.58" from the edge of the duct.

Pitot Position 2: 17 X 0.408 = 6.94" from the center of the duct.
Pitot Position 2: 8.5 – 6.94 = 1.56" from the edge of the duct.

Pitot Position 3: 17 X 0.250 = 4.25" from the center of the duct.
Pitot Position 3: 8.5 – 4.25 = 4.25" from the edge of the duct.

Pitot Position 4: 17 X 0.0 = 0.0" from the center of the duct.
Pitot Position 4: 8.5 – 0.0 = 8.5" from the edge of the duct.

To calculate the Pitot positions that are above the centerline of the duct perform the following:

Pitot Position 1: 17 X 0.466 = 7.92" from the center of the duct.
Pitot Position 1: 8.5 + 7.92 = 16.42" from the edge of the duct.

Pitot Position 2: 17 X 0.408 = 6.94" from the center of the duct.
Pitot Position 2: 8.5 + 6.94 = 15.44" from the edge of the duct.

Pitot Position 3: 17 X 0.25 = 4.25" from the center of the duct.
Pitot Position 3: 8.5 + 4.25 = 12.75" from the edge of the duct.

Pitot Position 4: 17 X 0.0 = 0.0" from the center of the duct.
Pitot Position 4: 8.5 – 0.0 = 8.5" from the edge of the duct.

To calculate the Pitot tube positions below the duct centerline for points 5, 6, and 7 at test ports 2 and 3 perform the following:

Pitot Position 5: 17 X 0.466 = 7.92" from the center of the duct.
Pitot Position 5: 8.5 – 7.92 = 0.58" from the edge of the duct.

Pitot Position 6: 17 X 0.25 = 4.25" from the center of the duct.
Pitot Position 6: 8.5 – 4.25 = 4.25" from the edge of the duct.

Pitot Position 7: 17 X 0.132 = 2.24" from the center of the duct.
Pitot Position 7: 8.5 – 2.24 = 6.26" from the edge of the duct.

The calculation for those points above the centerline of the duct is as follows:

Pitot Position 5: 17 X 0.466 = 7.92" from the center of the duct.
Pitot Position 5: 8.5 + 7.92 = 16.42" from the edge of the duct.

Pitot Position 6: 17 X 0.25 = 4.25" from the center of the duct.
Pitot Position 6: 8.5 + 4.25 = 12.75" from the edge of the duct.

Pitot Position 7: 17 X 0.132 = 2.24" from the center of the duct.
Pitot Position 7: 8.5 + 2.24 = 10.74" from the edge of the duct.

The round duct is calculated the same as for the equal area method except that the values from Figure 1-4 are used. To calculate the test port location first calculate the circumference of the duct using the following formula:

$$C = 2 \pi r$$

Where:

C = Circumference (Inches)

$\pi$ = 3.14159

r = radius (Inches)

The circumference is divided by 360 (360° in a circle) and then multiply this number by 60 (The test ports are 60° apart). This will give the distance between the test ports.

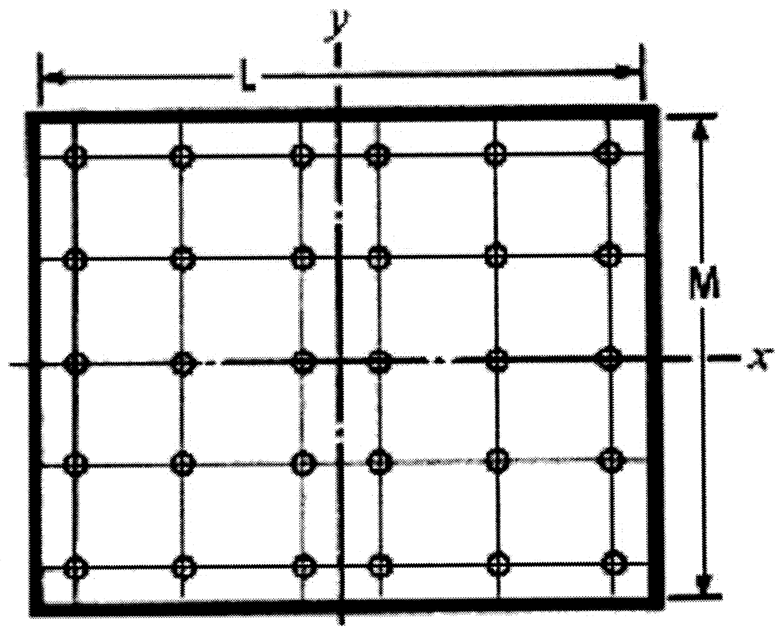
**2 X $\pi$ X 9 = 56.55" inches**

**56.55/360 = 0.1571 X 60 = 9.42"**

This is how far apart the test ports will be from each other.

- **Tchebycheff Method**

The third method is known as the log-Tchebycheff method. It is similar to the log-linear method for both the rectangular and round ducts but is not as complicated. This method uses a logarithmic distribution of velocities near the wall of the duct and polynomial distribution elsewhere. The following figure and table describe this method. All velocities are weighted equally.




Five rows are shown, with each row having six points.

| ROWS OR PTS/ROW | DISTANCE FROM CENTERLINE – (x or L) OR (y or M) | | | |
|---|---|---|---|---|
| 5 | 0 | ±0.212 | ±0.426 | |
| 6 | ±0.0630 | ±0.265 | ±0.439 | |
| 7 | 0 | ±0.134 | ±0.297 | ±0.447 |

**Figure 1-5: Tchebycheff Method for a Rectangular Duct**

Example:

Using Figure 1-5, assume a duct that has a dimension of 30" in the **L (x)** axis and 19" in the **M (y)** axis. To determine the location of the test ports that are to be installed on the bottom of the duct, perform the following:

Test Port Position 1: 30 X 0.439 = 13.17" from the center of the duct.
Test Port Position 1: 15 – 13.17 = 1.83" from the edge of the duct.

Test Port Position 2: 30 X 0.265 = 7.95" from the center of the duct.
Test Port Position 2: 15 – 7.95 = 7.05" from the edge of the duct.
Test Port Position 3: 30 X 0.063 = 1.89" from the center of the duct.
Test Port Position 3: 15 – 1.89 = 13.11" from the edge of the duct.

Test Port Position 4: 30 X 0.063 = 1.89" from the center of the duct.
Test Port Position 4: 15 + 1.89 = 16.89" from the edge of the duct.

Test Port Position 5: 30 X 0.265 = 7.95" from the center of the duct.
Test Port Position 5: 15 + 7.95 = 22.95" from the edge of the duct.

Test Port Position 6: 30 X 0.439 = 13.17" from the center of the duct.
Test Port Position 6: 15 + 13.17 = 28.17" from the edge of the duct.

To calculate the Pitot tube position for each test port use the five point section from Figure 1-5 as follows:

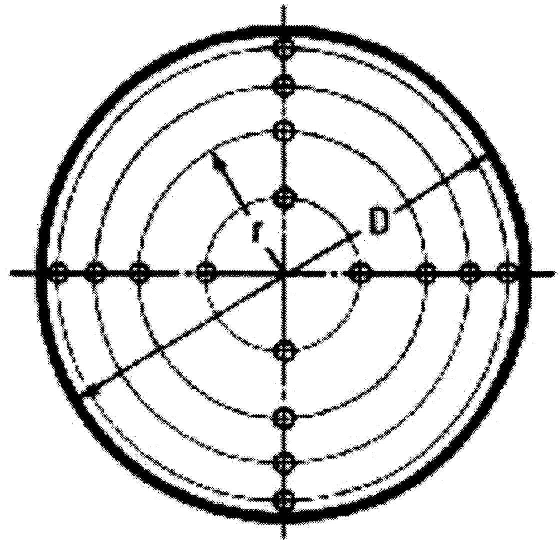
Test Port Position 1: 19 X 0.426 = 8.09" from the center of the duct.
Test Port Position 1: 9.5 – 8.09 = 1.41" from the edge of the duct.

Test Port Position 2: 19 X 0.212 = 4.03" from the center of the duct.
Test Port Position 2: 9.5 – 4.03 = 5.47" from the edge of the duct.

Test Port Position 3: 19 X 0.0 = 0.0" from the center of the duct.
Test Port Position 3: 9.5 – 0.0 = 9.50" from the edge of the duct.

Test Port Position 4: 19 X 0.212 = 4.03" from the center of the duct.
Test Port Position 4: 9.5 + 4.03 = 13.53" from the edge of the duct.

Test Port Position 5: 19 X 0.426 = 8.09" from the center of the duct.
Test Port Position 5: 9.5 + 8.09 = 17.59" from the edge of the duct.




Two diameters are shown, with each radius having four points.

| PTS. Per DIA | Distance From The Edge Of The Duct (Multiply the duct diameter by the number below) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 6 | 0.032 | 0.138 | 0.312 | 0.688 | 0.862 | 0.968 | | | | |
| 8 | 0.024 | 0.100 | 0.194 | 0.334 | 0.666 | 0.806 | 0.900 | 0.976 | | |
| 10 | 0.019 | 0.076 | 0.155 | 0.205 | 0.357 | 0.643 | 0.795 | 0.845 | 0.924 | 0.981 |

**Figure 1-6: Tchebycheff Method for a Round Duct**

The round duct is calculated the same as for the equal area method except that the values from Figure 1-6 are used.

**Traverse Qualification**

To determine if a traverse is located at a qualified position, apply the following from Figure 1-7. For any given traverse, round or rectangular, first find either the highest velocity in feet per minute or velocity pressure in inches of water. Divide this number by ten. Of all the readings combined, 75% or greater must be equal to or greater than this number. If the traverse does not meet these criteria then the traverse must not be used and will need to be relocated. Relocation of the traverse may require that more then one traverse will need to be located at various branch lines servicing the system.

As of this writing, this qualification standard is currently under review. The new proposal is as follows:

- 80 – 90% of the velocity measurements are greater than 10% of the maximum velocity for any given traverse.
- Airflow should be at right angles to the traverse plane.
- The duct at the traverse plane should not be irregular in shape.

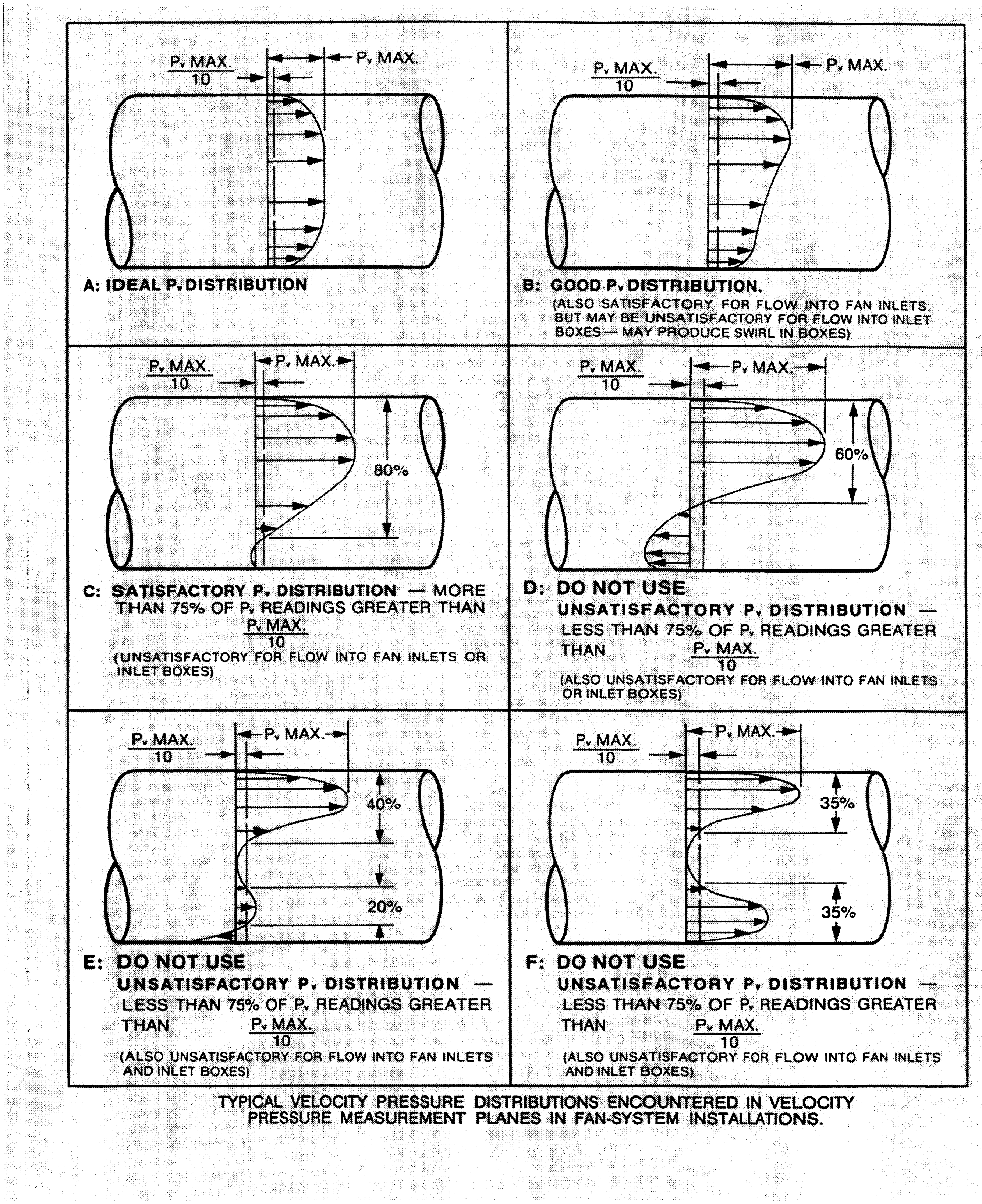



**Figure 1-7: Traverse Qualification (AMCA 203)**

# Air Side Flow Measurement

The following are four examples for calculating airflow from a traverse and if it is qualified. They are a rectangular duct using the equal area method, round duct using the log-Tchebycheff, and a rectangular log-linear method.

- **Example 1: Equal Area Method for a Rectangular Duct:**

  Given a 17" X 17" duct with a design flowrate of 4500 SCFM and a velocity profile shown below, calculate the airflow using the equal area method.

| Position | | 2⅛" | 6⅜" | 10⅝" | 14⅞" |
|---|---|---|---|---|---|
| 1 | FPM | 2078 | 2164 | 2235 | 2107 |
| 2 | FPM | 2184 | 2091 | 2162 | 2125 |
| 3 | FPM | 2259 | 2193 | 2199 | 2341 |
| 4 | FPM | 2326 | 2371 | 2423 | 2432 |
| **Subtotal** | **FPM** | **8847** | **8819** | **9019** | **9005** |

Total FPM = 8847 + 8819 + 9019 + 9005 = 35,690 FPM
Average FPM = 35,690 / 16 = 2231 FPM

Duct area, in square feet = 17" X 17" /144 = 289 in$^2$ / 144 = 2.01 Ft$^2$

Airflow in CFM = 2.01 Ft$^2$ X 2231 FPM = 4484 CFM

% of design = 4484 / 4500 X 100 = 99.6% of design

- **Example 2: Log-Tchebycheff Method for a Round Duct:**

  For round duct of 18" that has a design of 4500 CFM and the velocity profile shown below, calculate the airflow using the log-Tchebycheff method.

| Position | .34" | 1.37" | 2.79" | 3.69" | 6.43" | 11.57" | 14.31" | 15.21" | 16.63" | 17.66" | Subtotal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Vertical** | 2113 | 2123 | 2192 | 2178 | 2192 | 2626 | 2738 | 2749 | 2522 | 2231 | **23664** |
| **Horizontal** | 2549 | 2605 | 2588 | 2492 | 2349 | 2525 | 2818 | 2808 | 2616 | 2197 | **25547** |

Total FPM = 23664 + 25547 = 49,211 FPM
Average FPM = 49,211 / 20 = 2461 FPM

Duct area in square feet = $\pi r^2$ /144 = 3.14159 X 9$^2$ / 144 = 254.47 in$^2$ / 144 = 1.77 Ft$^2$

Airflow in CFM = 1.77 Ft$^2$ X 2461 FPM = 4356 CFM

% of design = 4356 / 4500 X 100 = 96.8% of design

- **Example 3: Log-Linear Method for a Rectangular Duct**

Given a 17" X 17" duct with a design flowrate of 4500 SCFM and a velocity profile shown below, calculate the airflow using the log-linear method.

| Position | 0.58"(1&5) | 1.56"(2) | 4.25"(3&6) | 6.26"(7) | 8.50"(4) | 10.74"(7) | 12.75"(3&6) | 15.44"(2) | 16.42"(1&5) |
|---|---|---|---|---|---|---|---|---|---|
| 1.56"(1) | 1848 | 1818 | 2059 | | 2161 | | 2048 | 1907 | 1826 |
| 6.26"(5) | 1867 | | 2088 | 2206 | | 2172 | 2197 | | 1930 |
| 10.74"(5) | 2332 | | 2303 | 2224 | | 2265 | 2290 | | 2111 |
| 15.44"(1) | 1716 | 1847 | 2410 | | 2472 | | 2423 | 2373 | 2223 |

Weighting values to be applied to each velocity:

| Position | 0.58"(1&5) | 1.56"(2) | 4.25"(3&6) | 6.26"(7) | 8.50"(4) | 10.74"(7) | 12.75"(3&6) | 15.44"(2) | 16.42"(1&5) |
|---|---|---|---|---|---|---|---|---|---|
| 1.56"(1) | 2 / 96 | 2 / 96 | 5 / 96 | | 6 / 96 | | 5 / 96 | 2 / 96 | 2 / 96 |
| 6.26"(5) | 3 / 96 | | 3 / 96 | 6 / 96 | | 6 / 96 | 3 / 96 | | 3 / 96 |
| 10.74"(5) | 3 / 96 | | 3 / 96 | 6 / 96 | | 6 / 96 | 3 / 96 | | 3 / 96 |
| 15.44"(1) | 2 / 96 | 2 / 96 | 5 / 96 | | 6 / 96 | | 5 / 96 | 2 / 96 | 2 / 96 |

Velocities after weighting values applied:

| Position | 0.58"(1&5) | 1.56"(2) | 4.25"(3&6) | 6.26"(7) | 8.50"(4) | 10.74"(7) | 12.75"(3&6) | 15.44"(2) | 16.42"(1&5) |
|---|---|---|---|---|---|---|---|---|---|
| 1.56"(1) | 38.5 | 37.9 | 107.2 | | 135.1 | | 106.7 | 39.7 | 38.0 |
| 6.26"(5) | 58.3 | | 65.3 | 137.9 | | 135.8 | 68.7 | | 60.3 |
| 10.74"(5) | 72.9 | | 72.0 | 139.0 | | 141.6 | 71.6 | | 66.0 |
| 15.44"(1) | 35.7 | 38.5 | 125.5 | | 154.5 | | 126.2 | 49.4 | 46.3 |
| **Subtotal** | **205.4** | **76.4** | **370.0** | **276.9** | **289.6** | **277.4** | **373.2** | **89.1** | **210.6** |

FPM = 205.4 + 76.4 + 370.0 + 276.9 + 289.6 + 277.4 + 373.2 + 89.1 + 210.6 = 2168.6 FPM

Duct area in square feet = 17" X 17" / 144 = 289 in$^2$ / 144 = 2.01 Ft$^2$

Airflow in CFM = 2.01 Ft$^2$ X 2168.6 FPM = 4359 CFM

% of design = 4359 / 4500 X 100 = 96.9% of design

**Example 4: Traverse Qualification**

Using example 3 of 1.3, determine if the traverse location is qualified.

First, identify the velocity that is the highest and the total number of points that comprise the traverse. The highest velocity is 2472 FPM located at the center of the duct at position 8.5" and 15.44", and the total number of traverse points is 26. The highest velocity value is then divided by ten.

2472 / 10 = 247.2

For any traverse, 75% of the total number of points must be larger than this calculated number.

Therefore:

26 X 0.75 =19.5 At least 20 of the 26 velocity readings must be above the value of 247.2 FPM.

Because there are no readings less then 247 FPM this is a qualified traverse. If, on the other hand there had been more then six velocity readings that were less then 247, this traverse would need to be relocated or other methods may need to be applied.

## AIR FLOW MEASUREMENT RESULTS

- **Summary**

Using the NUCON HVAC training unit, a series of airflow traverses were made at different locations using different methods. The unit is designed for a nominal capacity of 6,000 CFM but is operated at approximately 4000 CFM. The housing consists of a moisture separator section, heater section, Prefilter section, 1st stage HEPA filter section, adsorber section, and a 2nd stage HEPA filter section.

The ducting consists of a 17" x 17" square inlet duct that transitions to an 18"∅ round duct that has two 90° turns before it enters the housing. The outlet consists of an airfoil, backward inclined fan. It is a clock-wise (CW) rotation, top up blast (TUB) fan, rated at 6000 SCFM at 13.8" static pressure (SP), 19 horse power (HP), and 67% efficiency.

The outlet configuration attached to the fan is first, a variable position, perforated, multi-holed flow control damper attached to a 16.25" x 13.5" rectangular outlet duct. This duct transitions to a 90° elbow with turning vanes that transitions to a 13.5"∅ round duct. See figures 2-1 through 2-5 for more details.

The traverses are located in the 17" x 17" inlet duct (Traverse locations 1 & 2), at the 18"∅ round section before the 90° elbow (Traverse location 3 & 4) and midway between the two 90° elbows (Traverse location 5 & 6). On the outlet ducting the traverses are located on the

16.25" x 13.5" duct close to the fan (Traverse location 7 & 8), at the 16.25" x 13.5" duct close to the 90° elbow (Traverse location 9 & 10), and at the 13.5"∅ round outlet duct (Traverse location 11 & 12).

All traverses were installed so that they can accommodate any of the three traverse methods. At each of the traverses either an equal area, log-Tchebycheff, or log linear traverse was performed.

- **Method**

All traverses were performed on the same day during an approximate time period of three hours. Standard Pitot tubes were employed to traverse the ducts. A Shortridge ADM-870 Air Data Multimeter was used and set to the standard mode of operation with the temperature probe attached and inserted into the duct at the various traverse locations. Each traverse point was read three times consecutively and then averaged. This averaged velocity is the number that is recorded. All data points were first calculated by hand and then verified using an Excel spreadsheet.

The recommended traverse location is eight duct diameters downstream of any disturbances and two duct diameters upstream of any disturbances.

| | Traverse Location From Disturbances, In Duct Diameters | |
|---|---|---|
| **Traverse Number** | **Duct Diameters Downstream** | **Duct Diameters Upstream** |
| **Ideal** | **8** | **2** |
| **1** | 8.7 | 2.6 |
| **2** | 9.5 | 1.8 |
| **3** | 7.8 | 4.3 |
| **4** | 9.6 | 2.6 |
| **5** | 2.3 | 1.0 |
| **6** | 2.6 | 0.6 |
| **7** | 1.6 | 4.9 |
| **8** | 1.6 | 4.9 |
| **9** | 4.3 | 0.6 |
| **10** | 4.3 | 0.6 |
| **11** | 5.9 | 1.4 |
| **12** | 5.9 | 1.4 |

- **Results**

Refer to the following table for a compilation of the test results. An average of traverses 2 (Log-Tchebycheff), 3 (Log-Linear), 4 (Log-Linear), 11 (Log-Linear), and 12 (Log Tchebycheff) were used to set a benchmark airflow to compare all of the traverses to.

Out of twenty airflows taken, the range of percent difference from the benchmark airflow was a low of –1.7% and a high of +13.5%. Eight traverses (#'s 2 (L-T), 2 (L-L), 3 (E-A), 3 (L-T), 3 (L-L), 6 (E-A (H & V)), 11 (L-L), and 12 (L-T)) have less than a 1% deviation from the benchmark airflow. Two of the traverse locations are not qualified based on AMCA 203.

## Test Results Summary

| TRAVERSE LOCATION # & TYPE | SCFM | % OF DESIGN | % OF 4058 SCFM | AVERAGE SFPM | MINIMUM SFPM | MAXIMUM SFPM |
|---|---|---|---|---|---|---|
| **17" x 17"** | | | | | | |
| (#1) E-A | 4185 | 104.6 | +3.1 | 2085 | 1629 | 2303 |
| (#2) L-T | 4055 | 101.4 | -0.07 | 2021 | 1252 | 2230 |
| (#2) L-L | 4060 | 101.5 | +0.04 | 1979 | 1483 | 2279 |
| **18" Ø Pre Elbow** | | | | | | |
| (#3) E-A | 4074 | 101.9 | +0.39 | 2306 | 1950 | 2689 |
| (#3) L-T | 4045 | 101.1 | -0.32 | 2289 | 1794 | 2628 |
| (#4)L-L | 4056 | 101.4 | -0.05 | 2296 | 1924 | 2605 |
| **18" Ø Post Elbow** | | | | | | |
| (#6) E-A (40 Pt.) | 4269 | 106.7 | +5.2 | 2416 | 400 | 2892 |
| (#6) E-A (H & V) | 4050 | 101.3 | -0.20 | 2292 | 400 | 2892 |
| (#6) E-A (Dia.) | 4487 | 112.2 | +10.6 | 2540 | 1768 | 2755 |
| (#6) L-T | 3991 | 99.8 | -1.7 | 2258 | 0 | 3018 |
| (#5) L-L | 3990 | 99.8 | -1.7 | 2258 | 0 | 2910 |
| **Outlet Low** | | | | | | |
| (#8) E-A | 4322 | 108.0 | +6.5 | 2838 | 0 | 6247 |
| (#7) L-T | 4261 | 106.5 | +5.0 | 2798 | 0 | 7016 |
| (#7) L-L | 4516 | 112.9 | +11.3 | 3124 | 0 | 7077 |
| **Outlet High** | | | | | | |
| (#10) E-A | 4604 | 115.1 | +13.5 | 3021 | 1737 | 4288 |
| (#9) L-T | 4376 | 109.4 | +7.8 | 2871 | 1437 | 4528 |
| (#9) L-L | 4436 | 110.9 | +9.3 | 2981 | 1420 | 4608 |
| **13.5 Ø Outlet** | | | | | | |
| (#12) E-A | 4189 | 104.7 | +3.2 | 4214 | 3611 | 4587 |
| (#12) L-T | 4082 | 102.0 | +0.59 | 4106 | 3438 | 4437 |
| (#11) L-L | 4049 | 101.2 | -0.22 | 4073 | 3443 | 4512 |
| **Ave. Of #2 (L-T + L-L) + #3 (L-T) + #4 (L-L) + #11 (L-L) + #12 (L-T) / 6** | | | | | | |
| 4055+4060+ 4045+4056+ 4082+4049/6 | 4058 | 101.5 | 0.0 | N/A | N/A | N/A |

## Conclusions

Traverses 1,2,3 and 4 are located in almost ideal locations and should yield results that are close to identical. The equal-area method (traverse 1) on the 17" x 17" shows a slightly higher flow when compared to the other two methods for the same duct. All three methods performed on the 18" round duct before any disturbances show a very good correlation. In all cases except for one, the equal area method produced higher test results when compared to the other two methods, for the same location.

Of all the traverses two should not be used because the do not meet the AMCA 203 traverse qualification requirements with a third one just meeting the requirements. Taking readings to close to a fan outlet tends to overestimate the actual airflow that exists in the system. Of the remaining traverses, several others should be disqualified based on the velocity profile.

While the three methods used on a round duct produce similar results on larger, medium velocity ducts, it appears that the same over estimation occurs for the equal-area method on smaller high velocity ducts. This over estimation is present in the square duct when the equal-area method is used.

## References

HPAC Magazine "Equal Area vs. Log-Tchebycheff" December 1999

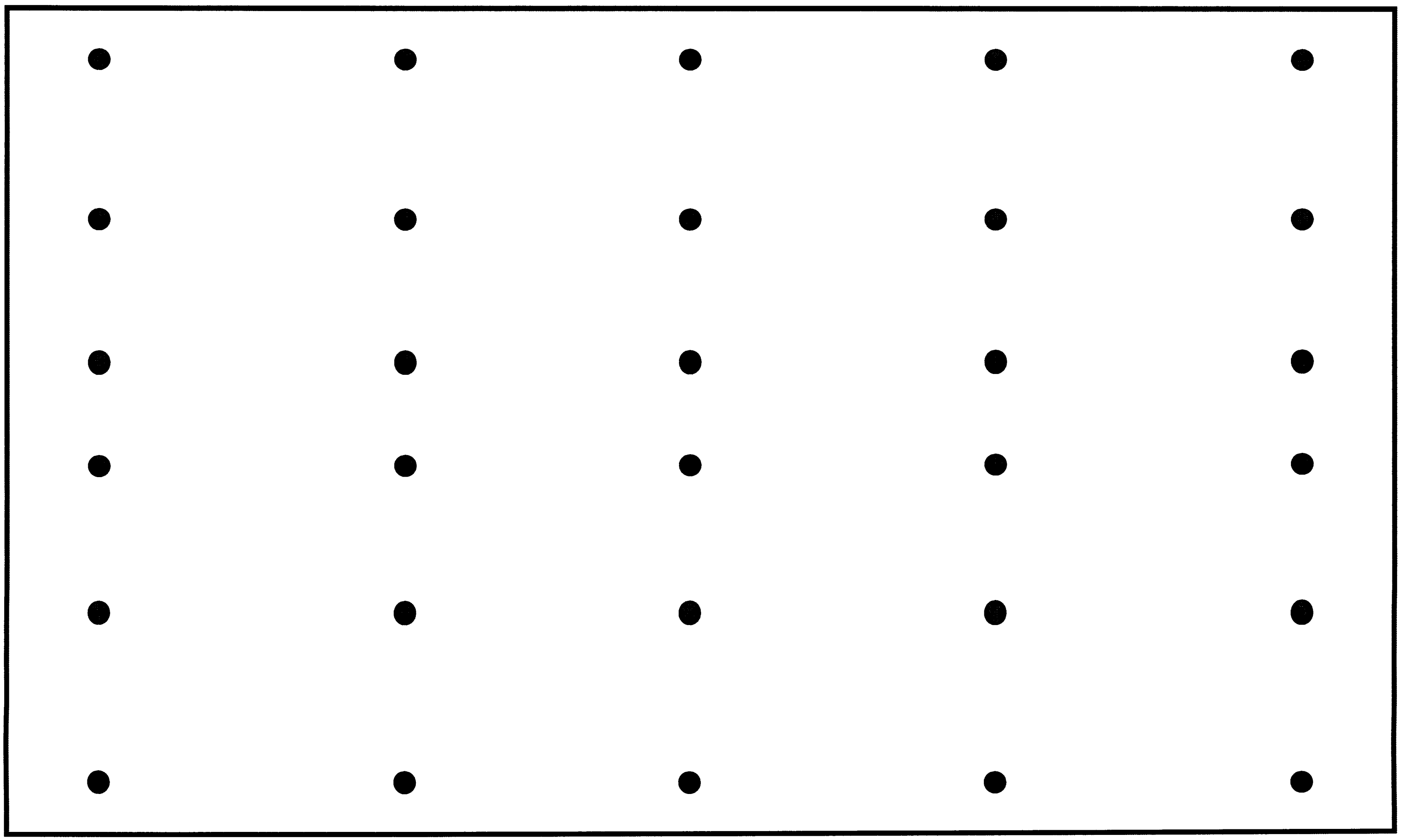
HPAC Magazine "Equal Area vs. Log-Tchebycheff Revisited" March 2001

Buffalo Forge Company "Fan Engineering Handbook" 8th Edition

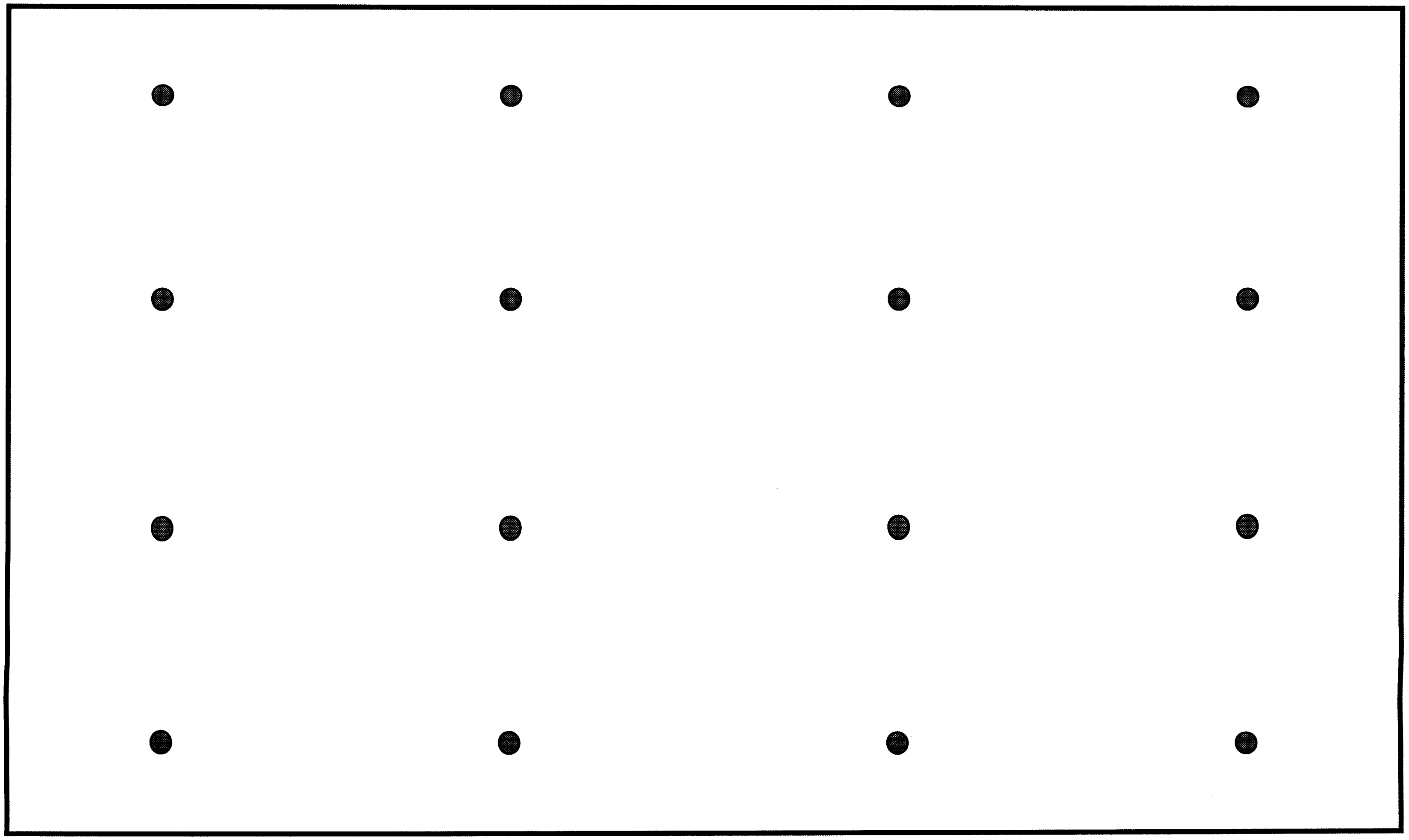
AMCA 203-90 "Field Performance Measurement Of Fan Systems"

ASHRAE 111-1988 "Practices For Measurement, Testing, Adjusting, And Balancing of Building Heating, Ventilation, Air-Conditioning, And Refrigeration Systems"

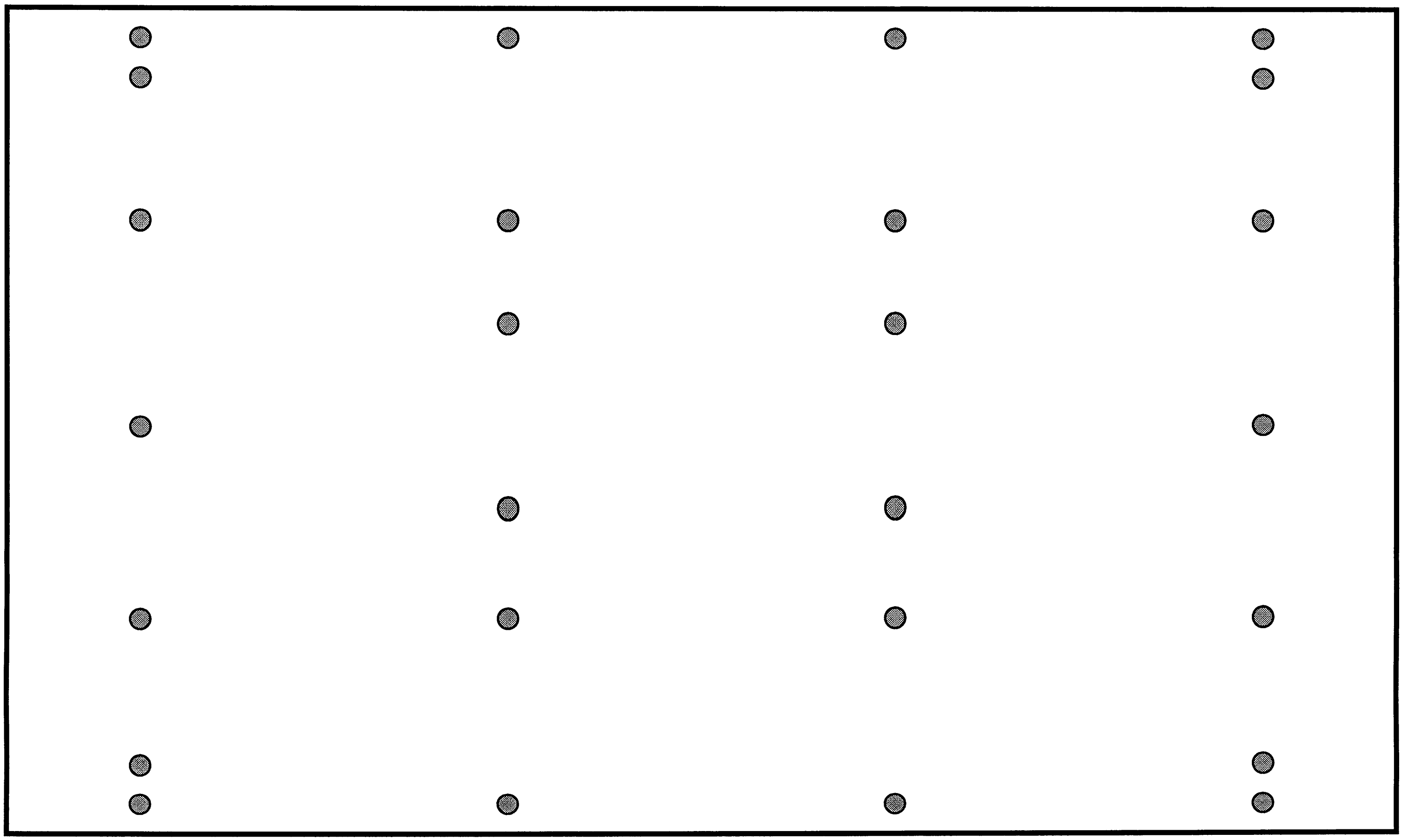
# LOG-TCHEBYCHEFF



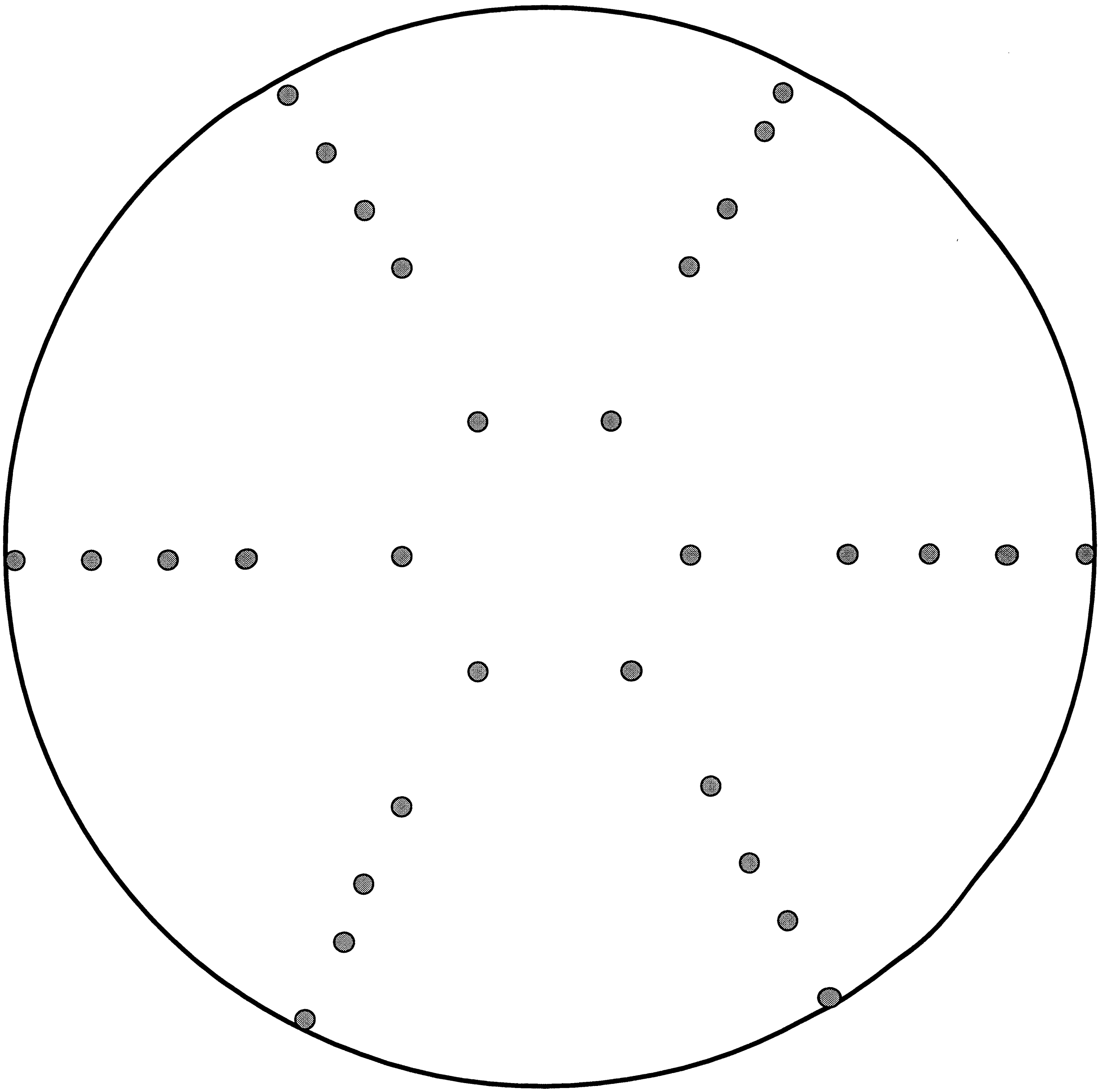
# EQUAL-AREA



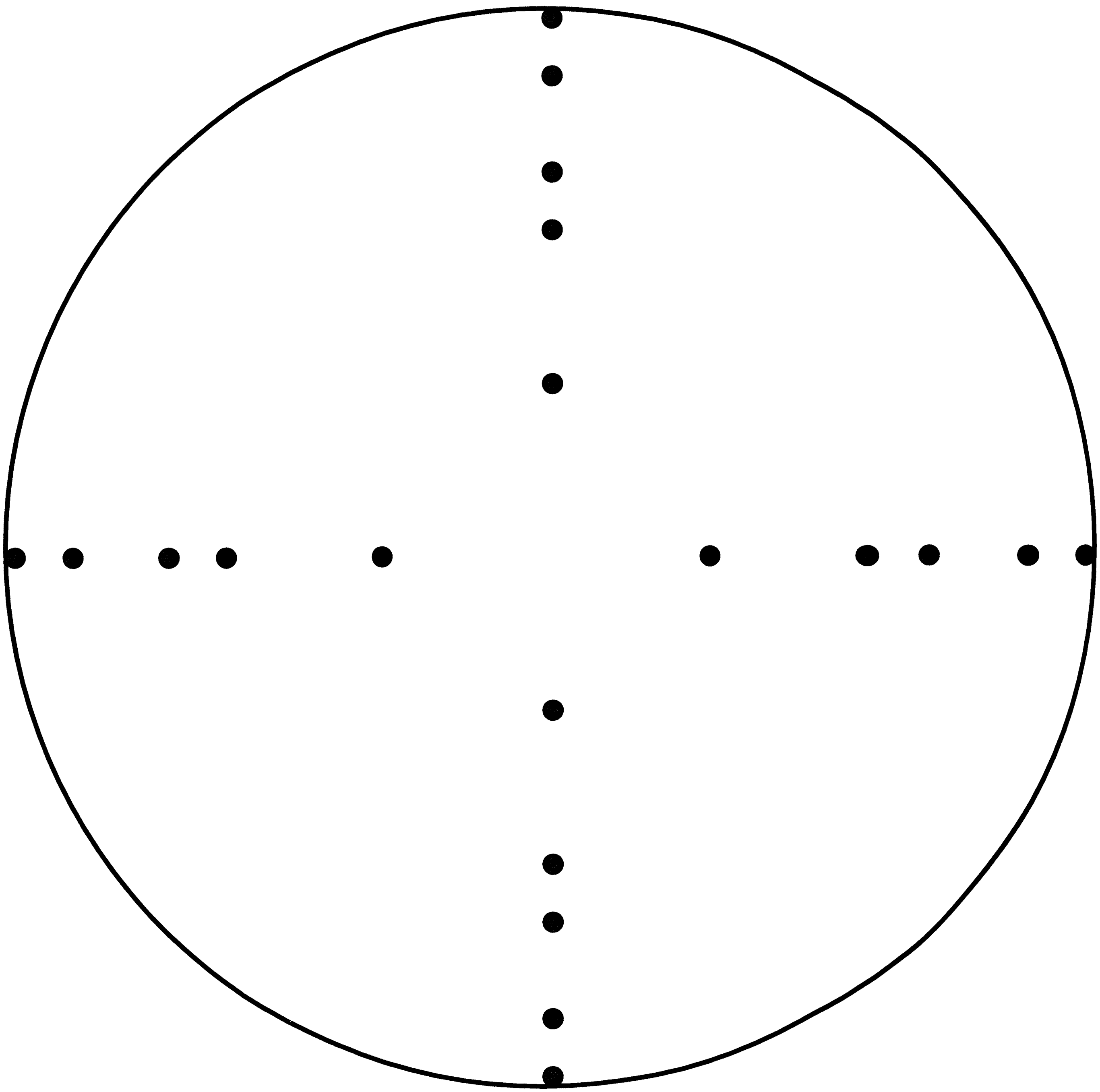
# LOG-LINEAR



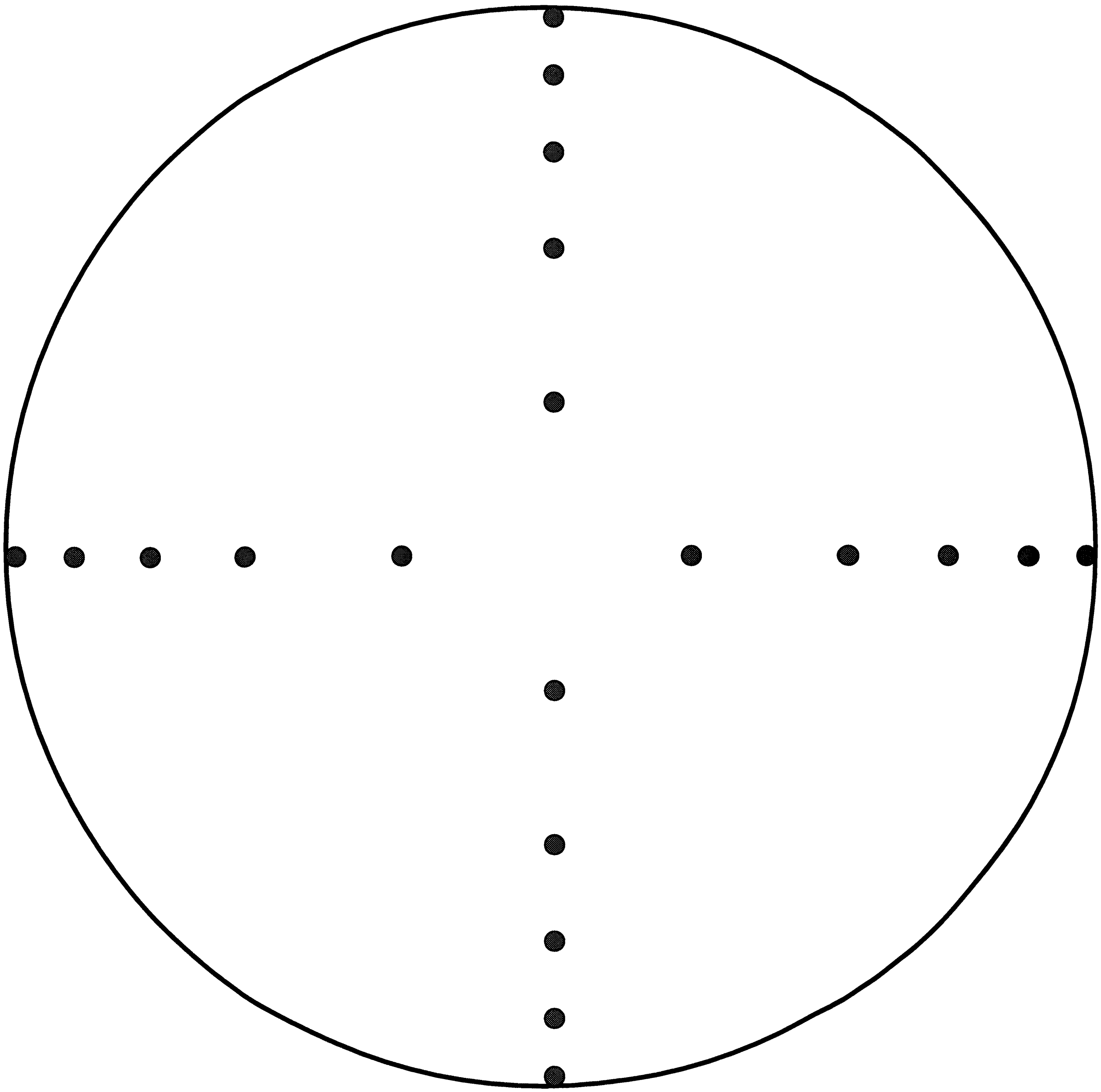
## LOG-LINEAR



# LOG-TCHEBYCHEFF

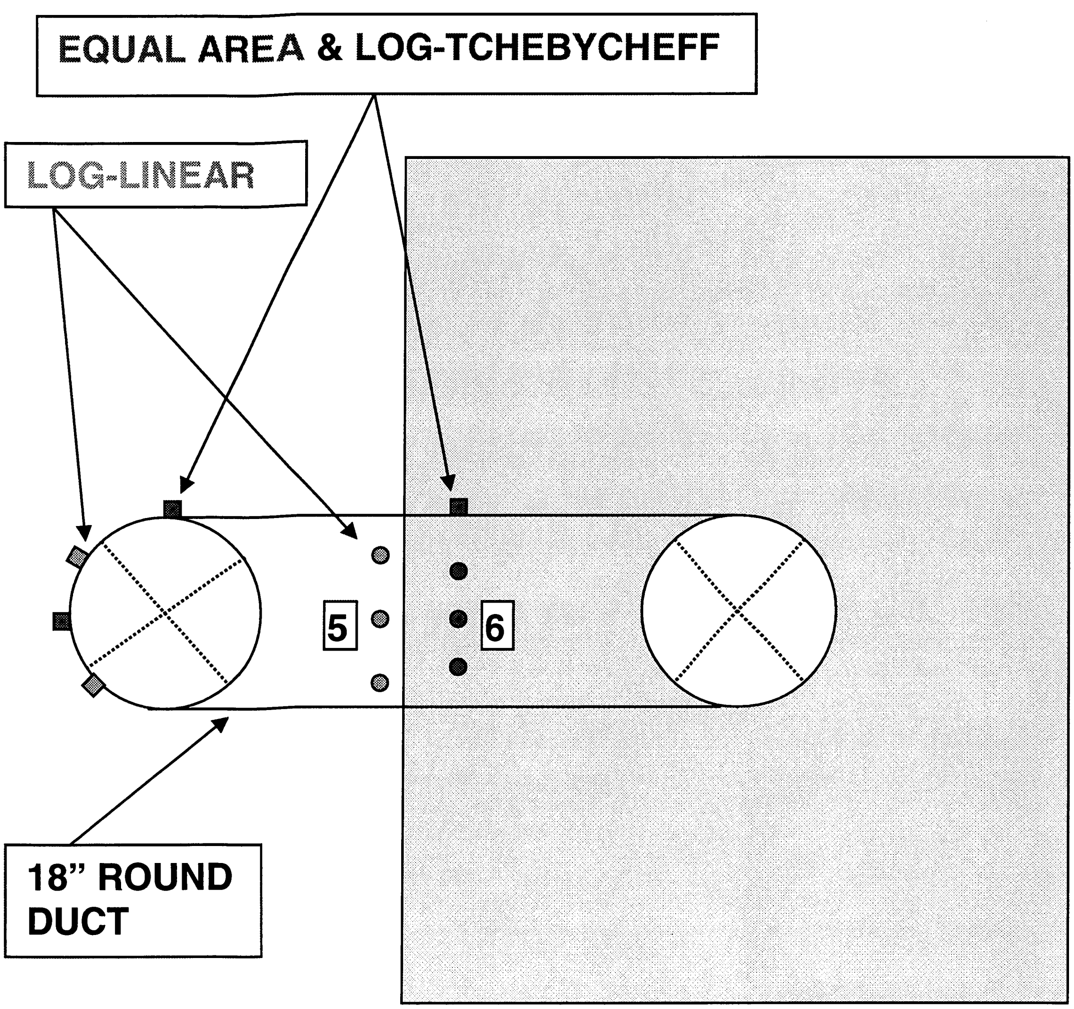


# EQUAL AREA



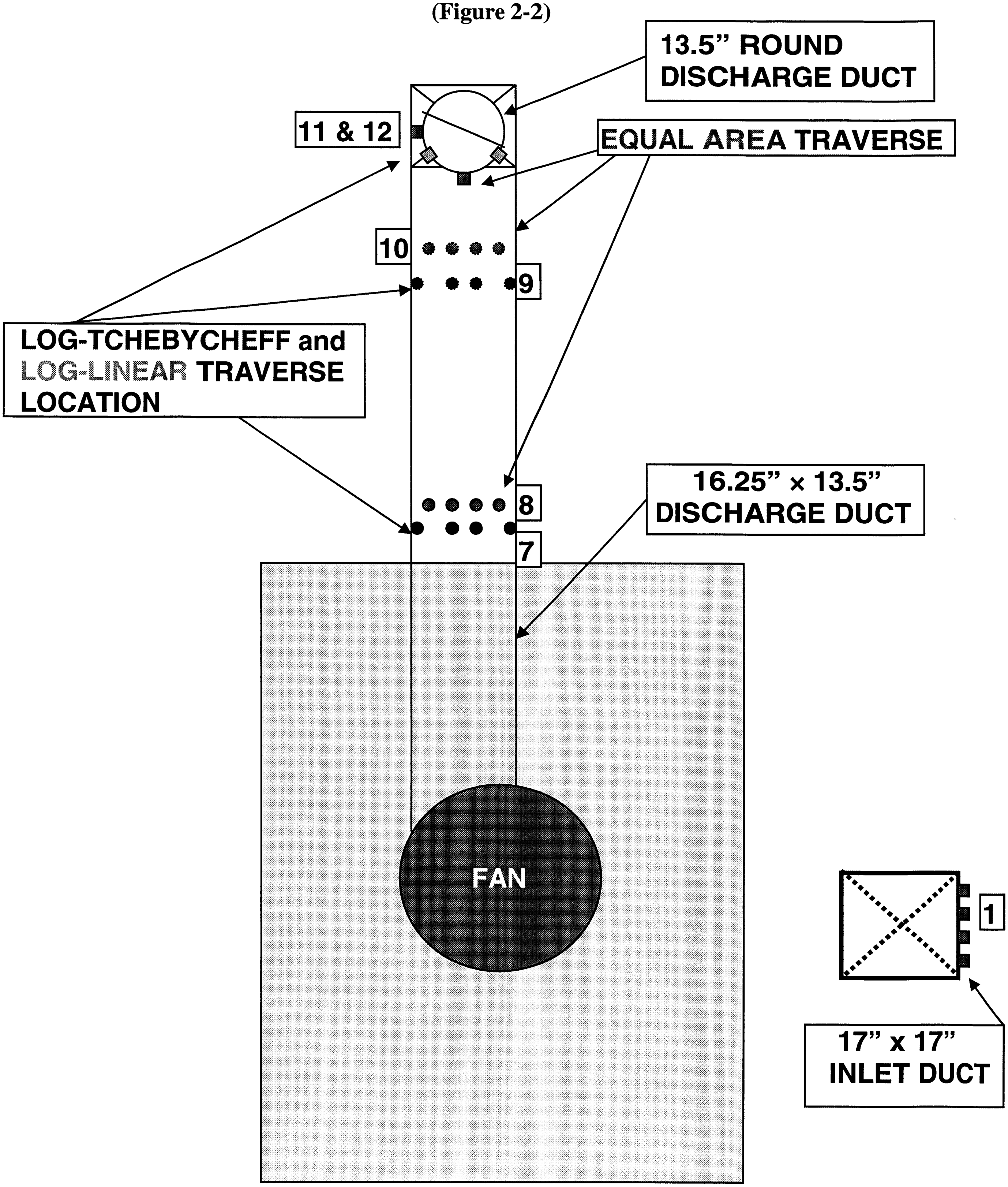
# INLET END ELEVATION VIEW

(Figure 2-1)



# OUTLET END ELEVATION VIEW

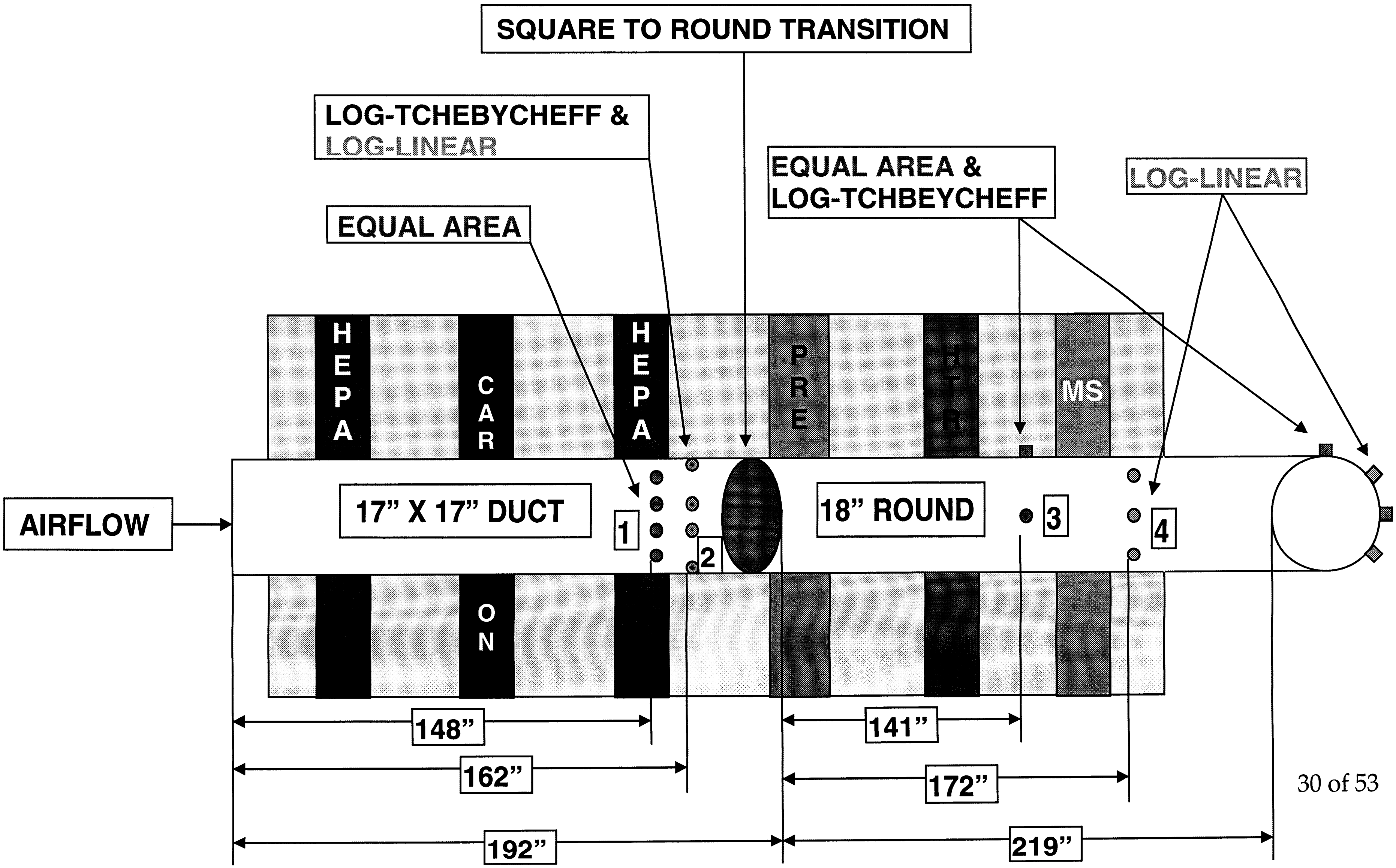
(Figure 2-2)



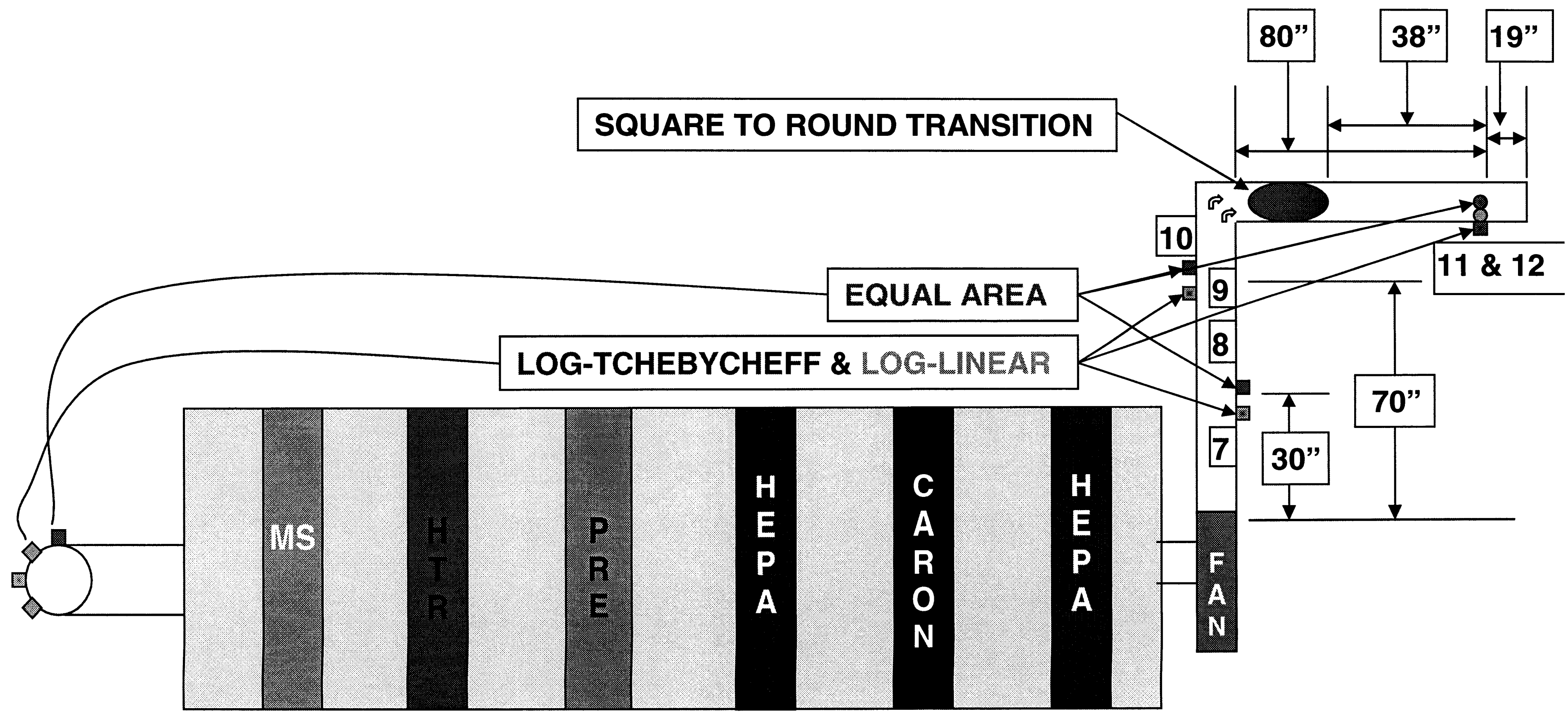
# Traverse Location

## (Elevation View)

(Figure 2-3)



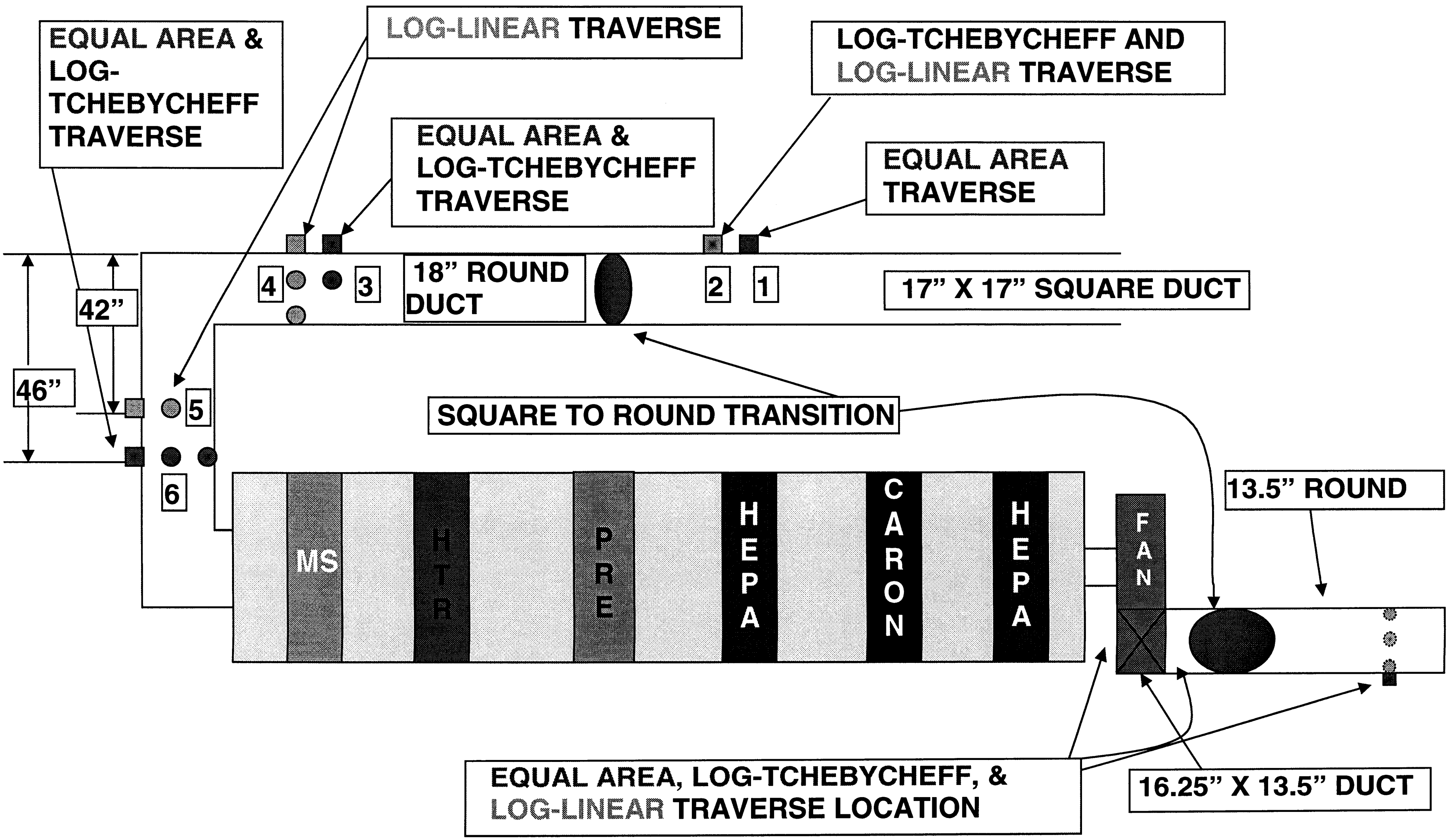
# Traverse Location
## (Elevation View)
(Figure 2-4)



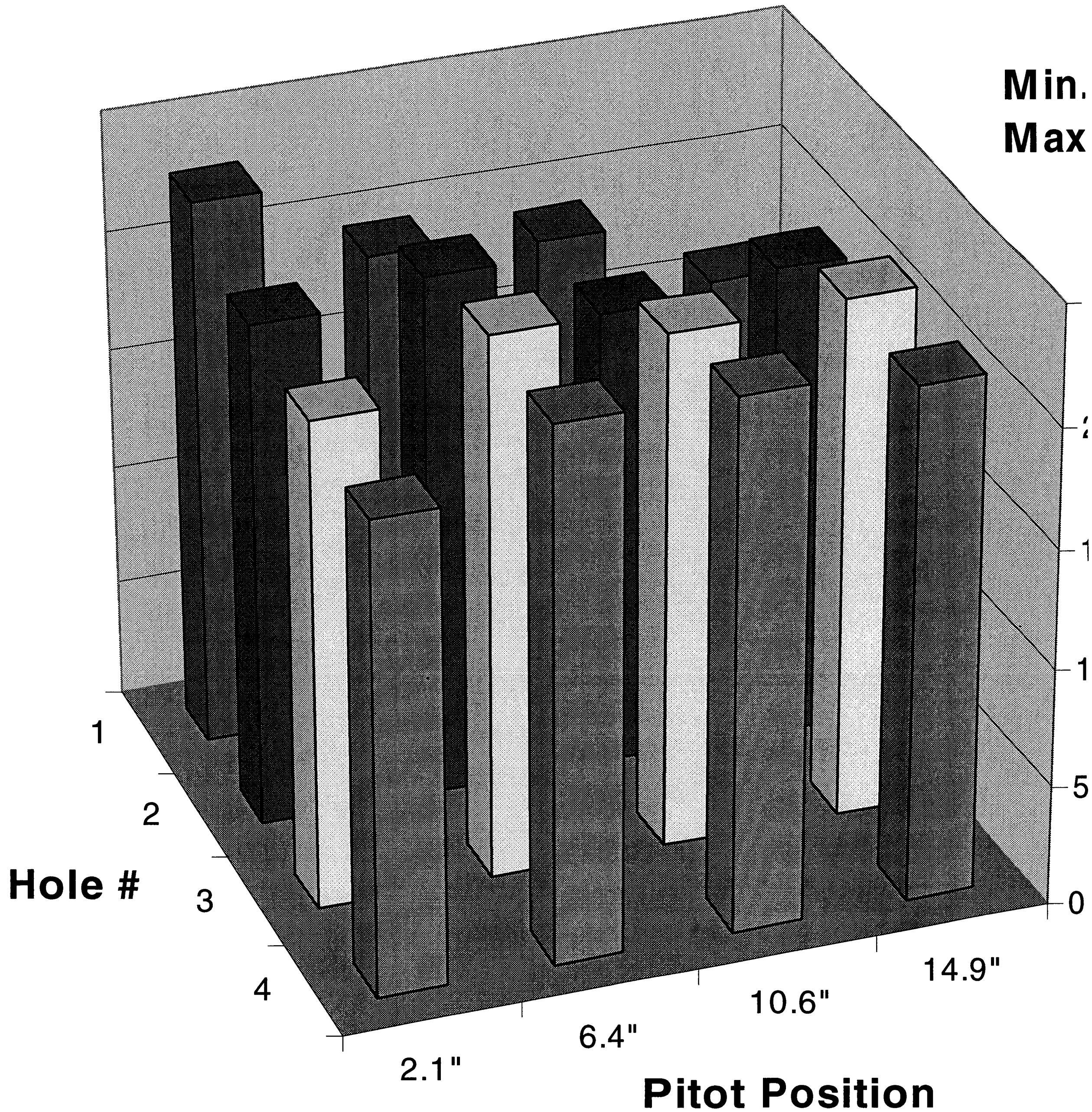
# Traverse Location

## (Plan View)

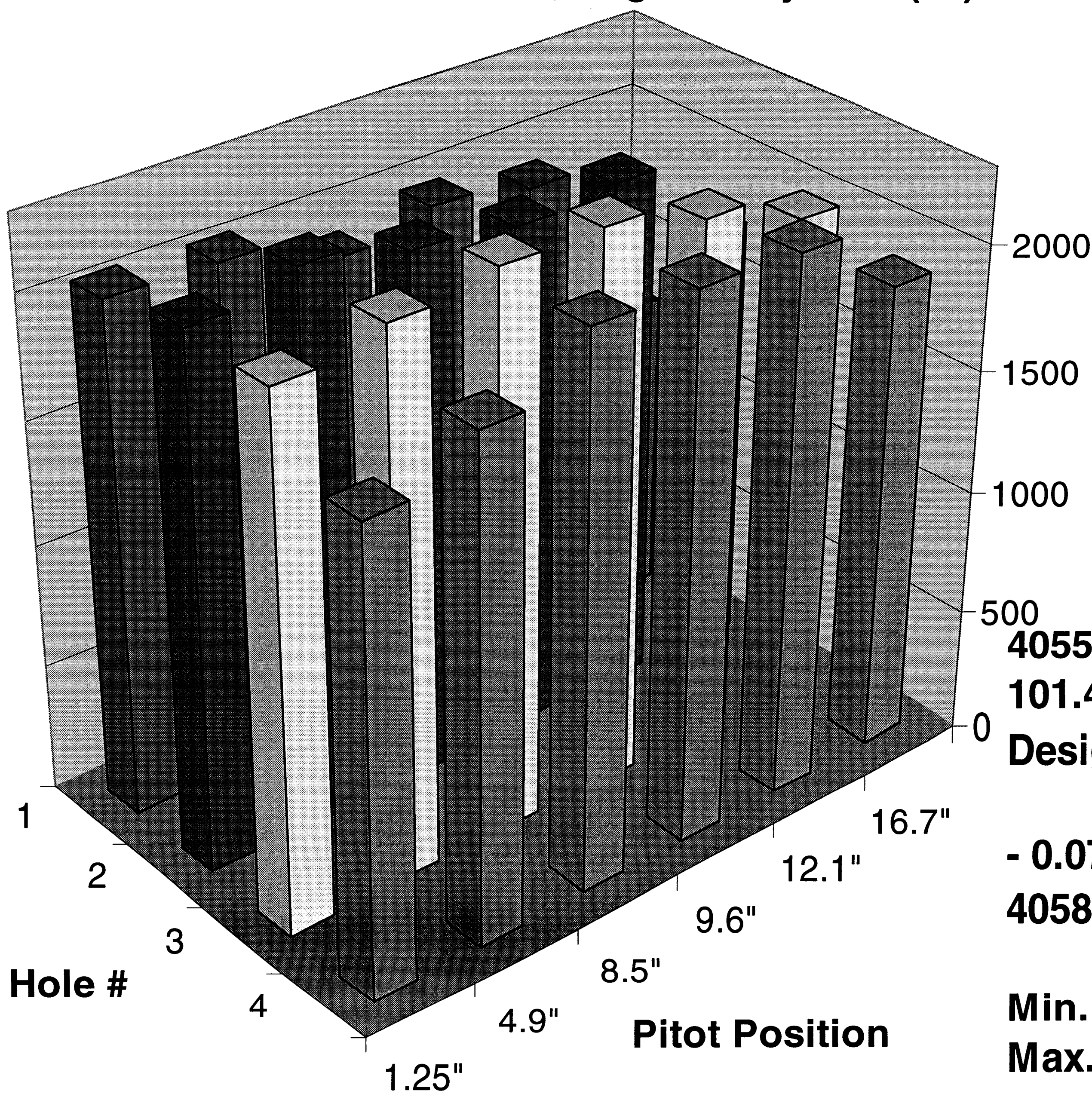
(Figure 2-5)



## 17" x 17" Inlet Duct, Equal Area Traverse (#1



# 17" x 17" Inlet Duct, Log-Tchebycheff (#2)

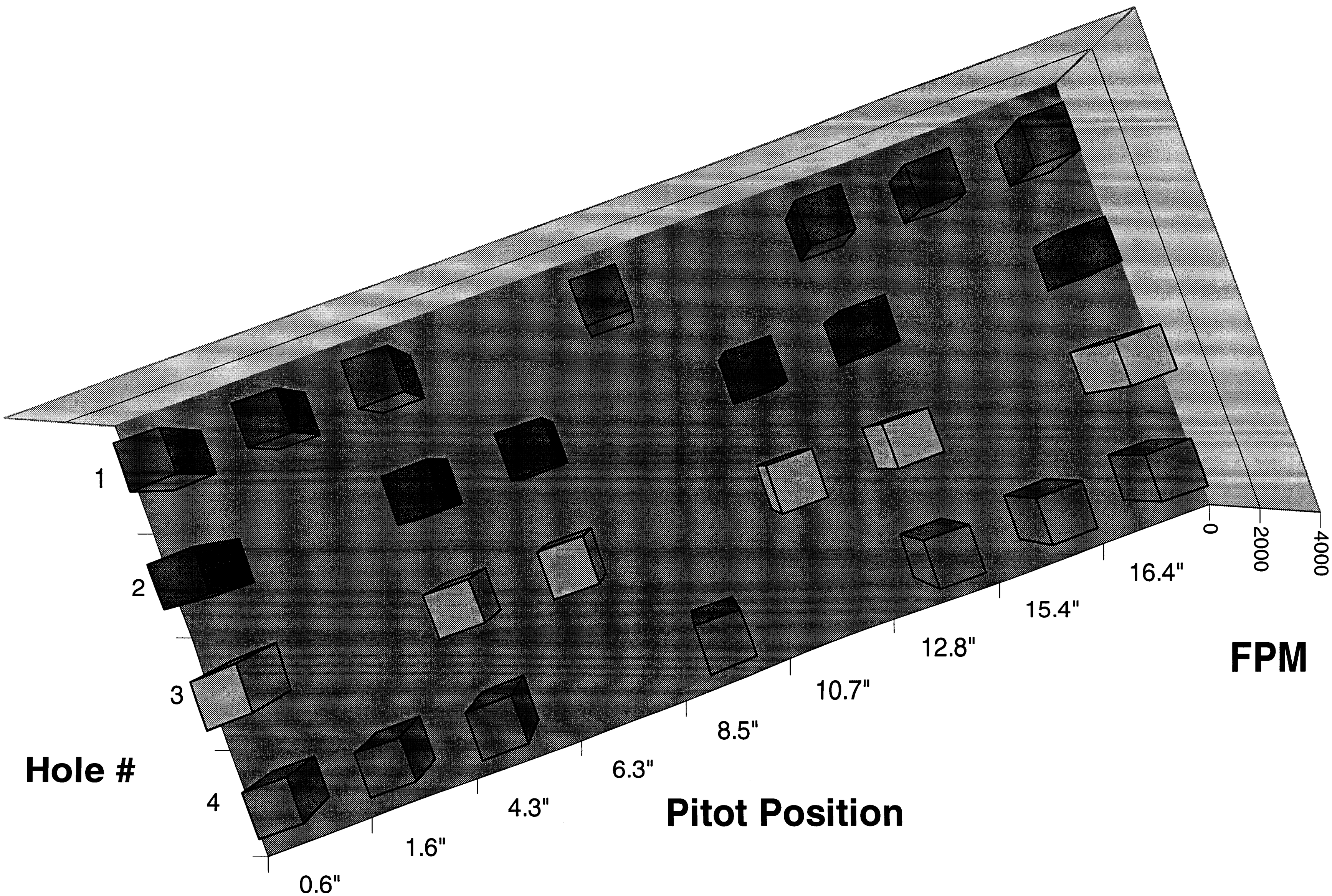



**4055 SCFM, 101.4% of Design**

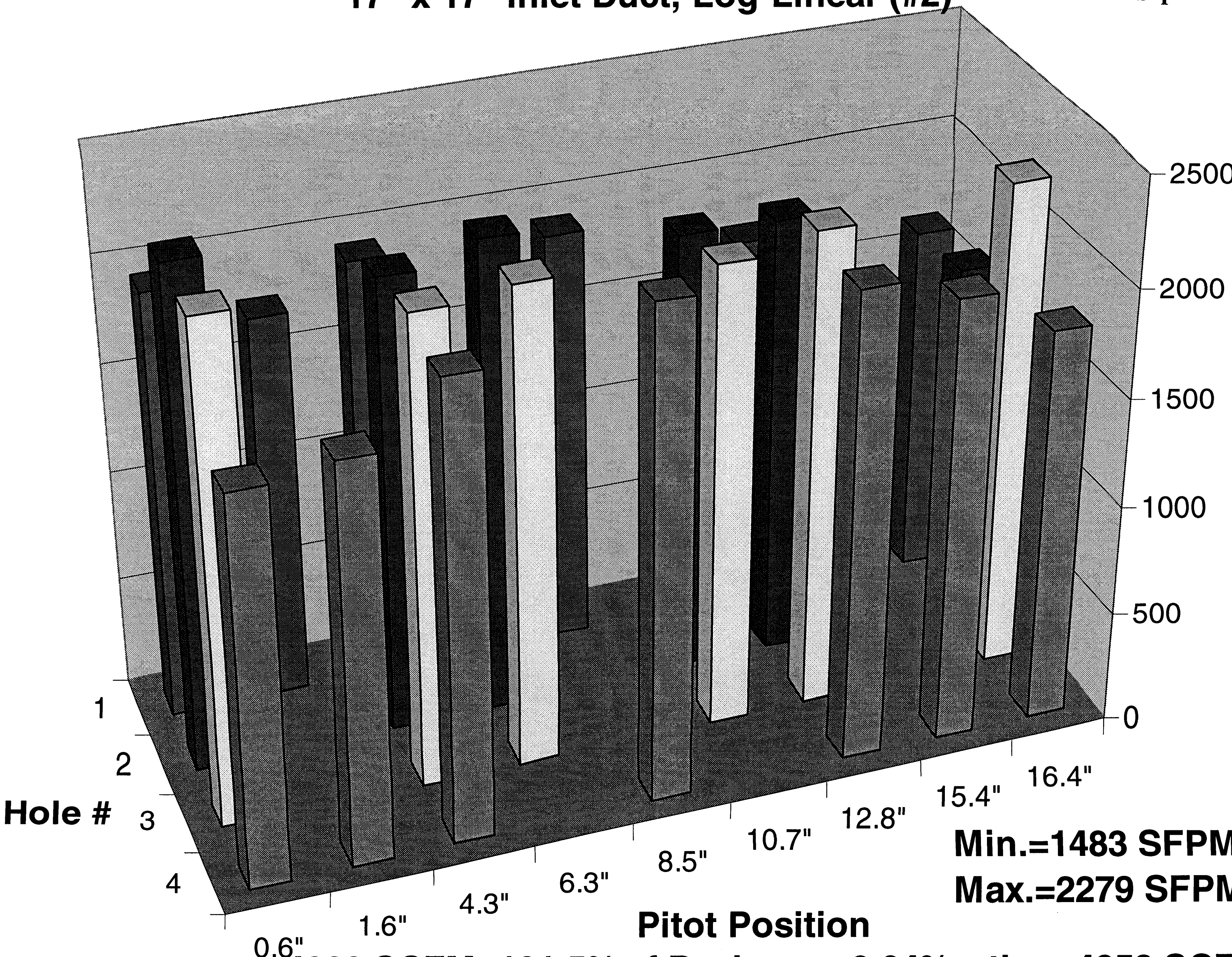
**- 0.07% < than 4058 SCFM**

**Min. = 1252 SFPM**
**Max. = 2230 SFPM**

# 17" x 17" Inlet Duct, Log-Linear (#2)

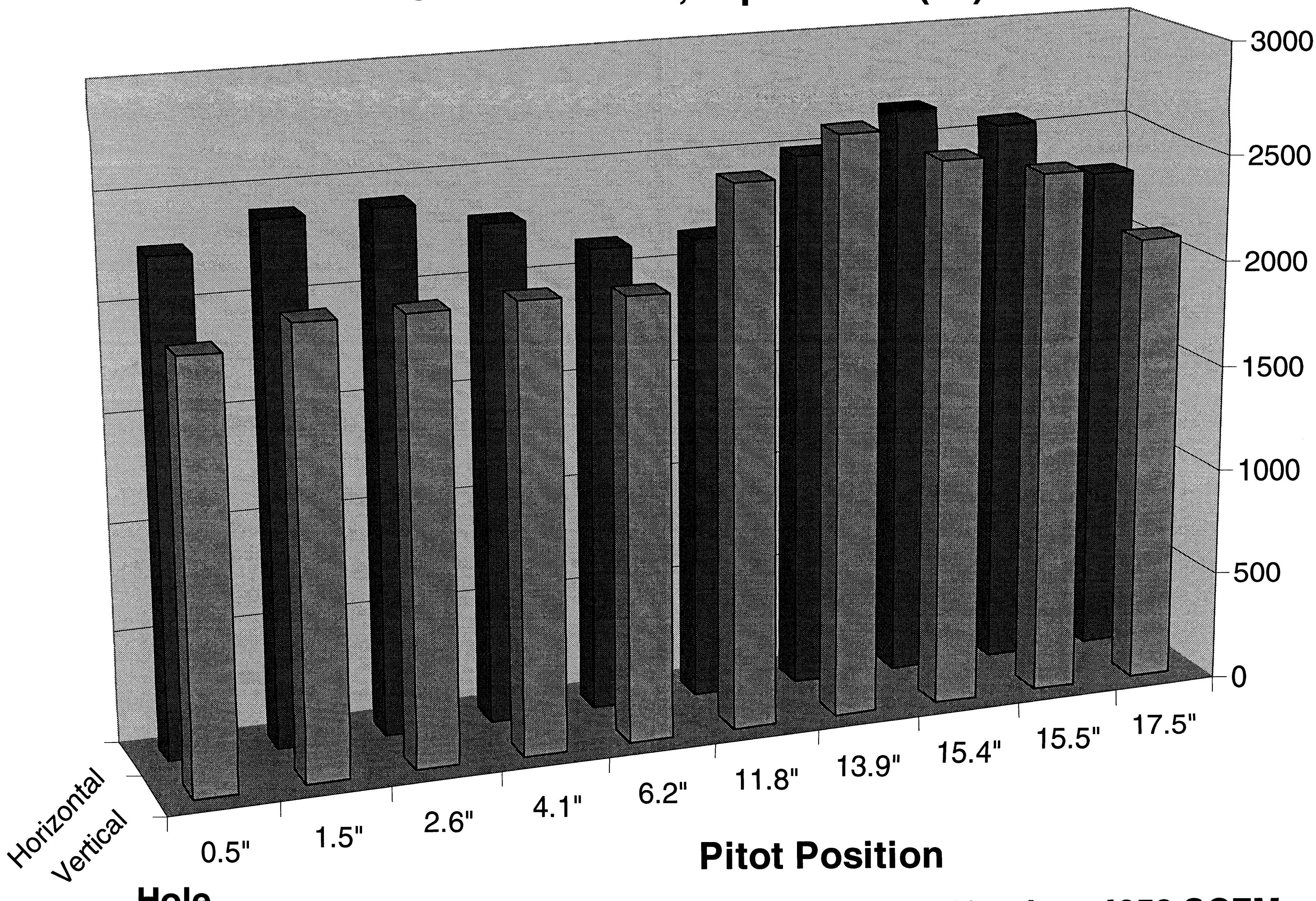


## 17" x 17" Inlet Duct, Log-Linear (#2)




**4060 SCFM, 101.5% of Design. +0.04% > than 4058 SCFM**

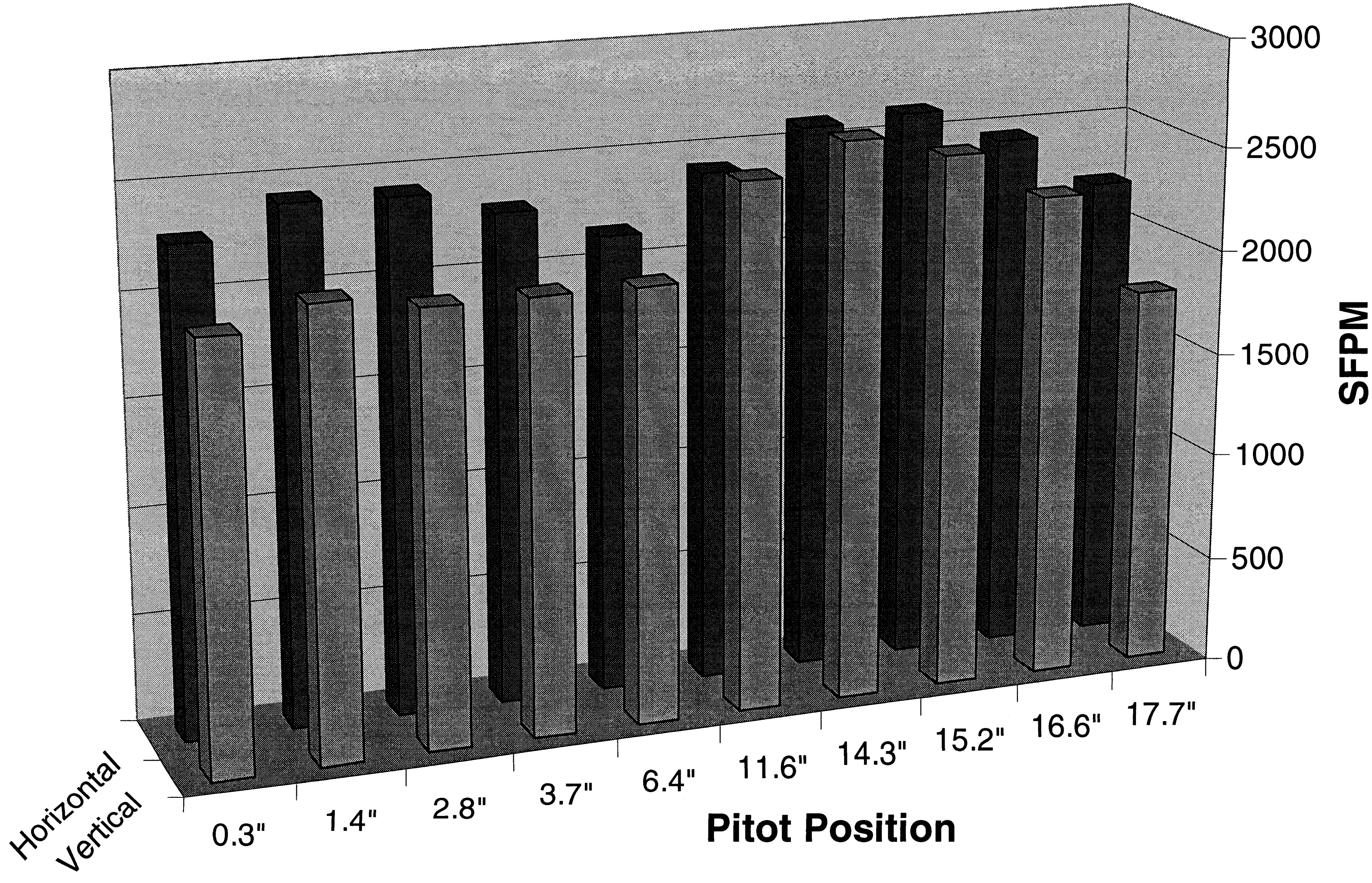
# 18" Round Inlet, Equal Area (#3)




**4074 SCFM, 101.9% of Design. +0.39% > than 4058 SCFM**

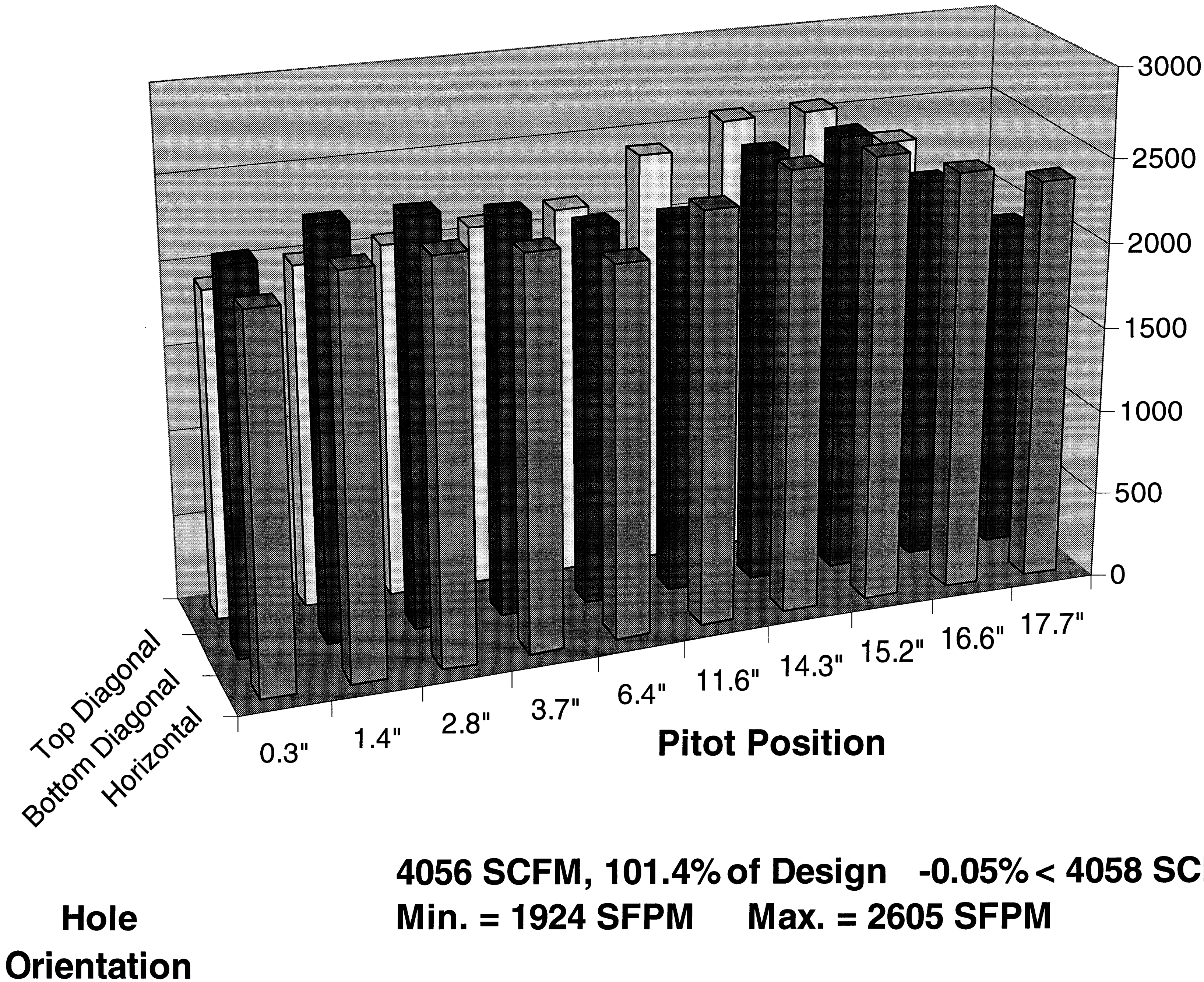
**Min. = 1950 SFPM     Max. = 2689 SFPM**

## 18" Round, Pre-Elbow, Log-Tchebycheff (# 3)




**4045 SCFM, 101.1% of Design. -0.32% < than 4058 SCFM**
**Min. = 1794 SFPM Max. = 2628 SFPM**

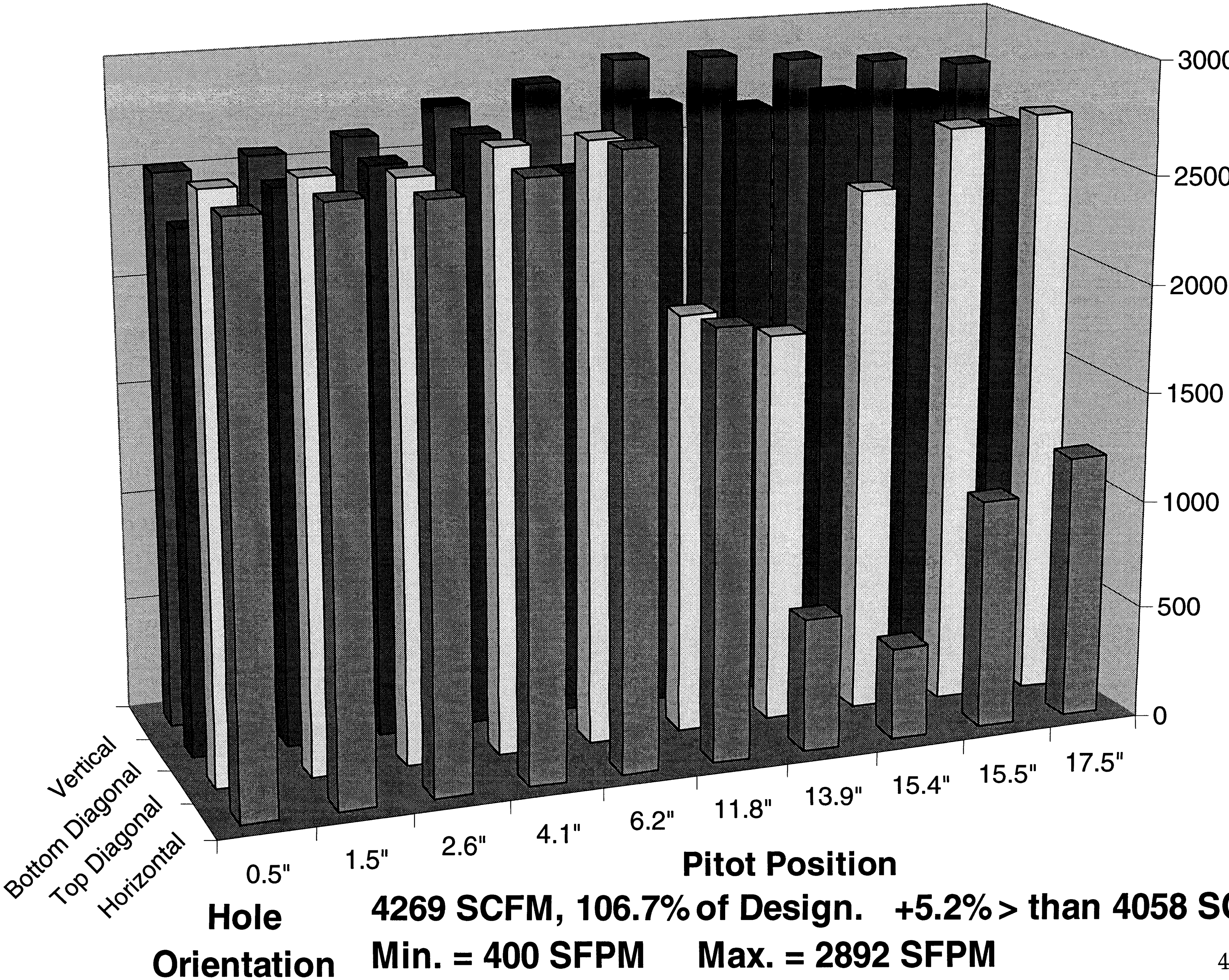
## 18" Round, Pre-Elbow, Log-Linear (#4)




**4056 SCFM, 101.4% of Design -0.05% < 4058 SCFM**

**Min. = 1924 SFPM Max. = 2605 SFPM**

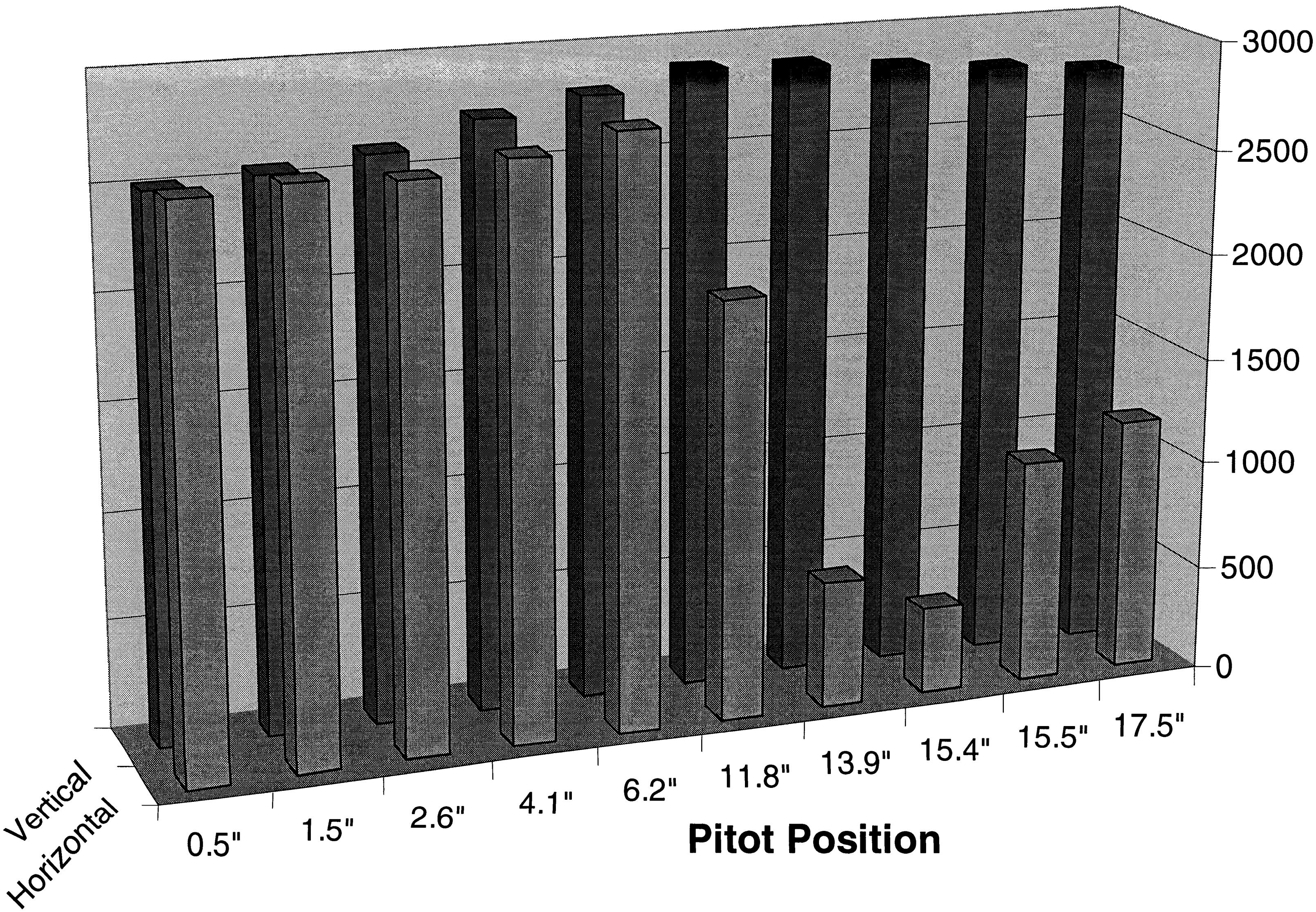
# 18" Round, Post Elbow, Equal Area (#6)




**4269 SCFM, 106.7% of Design. +5.2% > than 4058 SCFM**

**Min. = 400 SFPM Max. = 2892 SFPM**

## 18" Round, Post-Elbow, Vert. & Horiz. Only (#6)

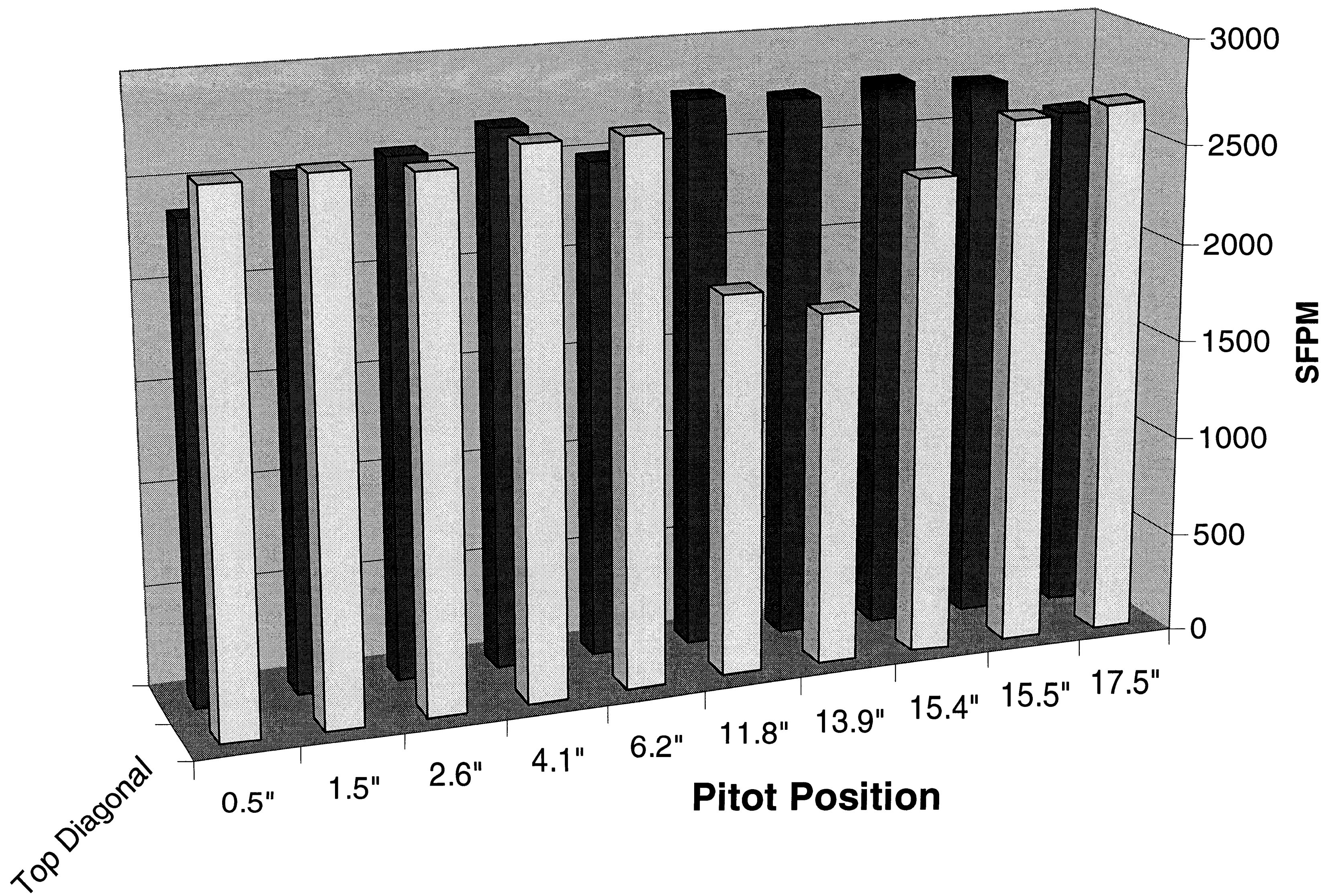



**Hole Orientation**

**4050 SCFM, 101.3% of Design. -0.20% < than 4058 SCFM**

**Min. = 400 SFPM Max. = 2892 SFPM**

## 18" Round, Post-Elbow, Diagonals Only (#6)

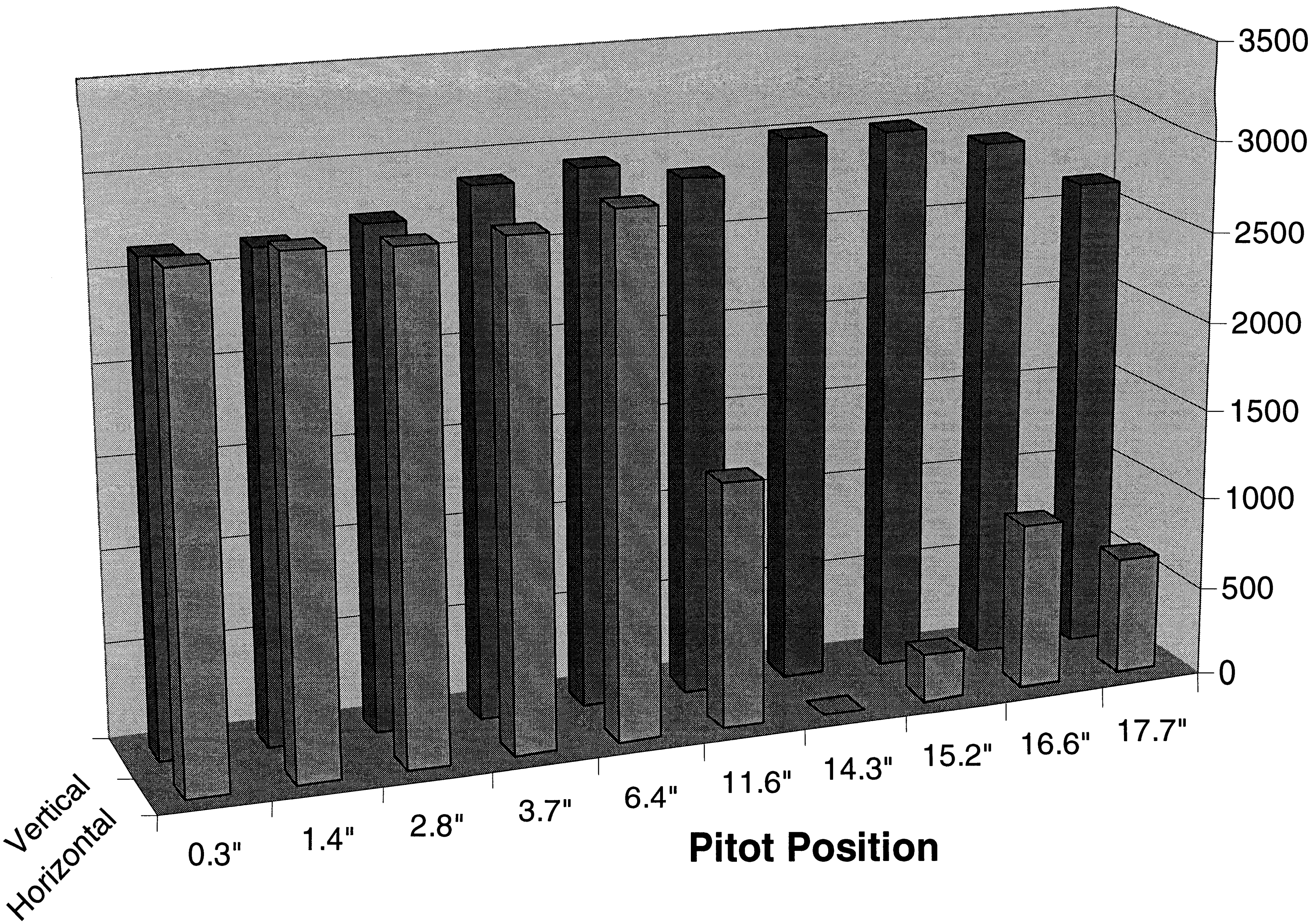



**4487 SCFM, 112.2% of Design. +10.6 % > than 4058 SCFM**

**Min. = 1768 SFPM Max. = 2755 SFPM**

**Hole Orientation**

# 18" Round, Post-Elbow, Log-Tchebycheff (#6)

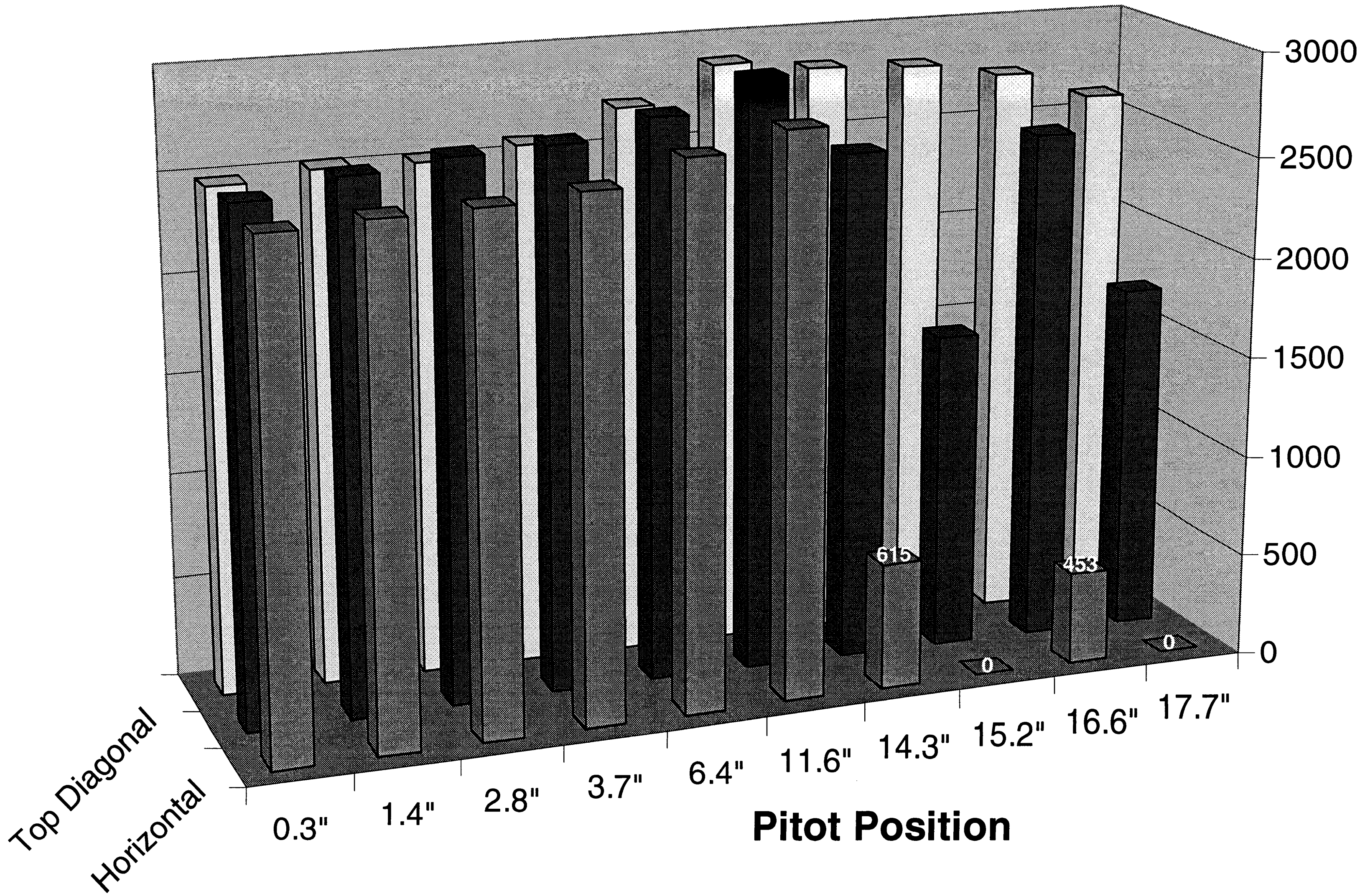



**Hole Orientation**

**3991 SCFM, 99.8% of Design. -1.7% < than 4058 SCFM**

**Min. = 0 SFPM Max. = 3018**

# 18" Round, Post-Elbow, Log-Linear (#5)

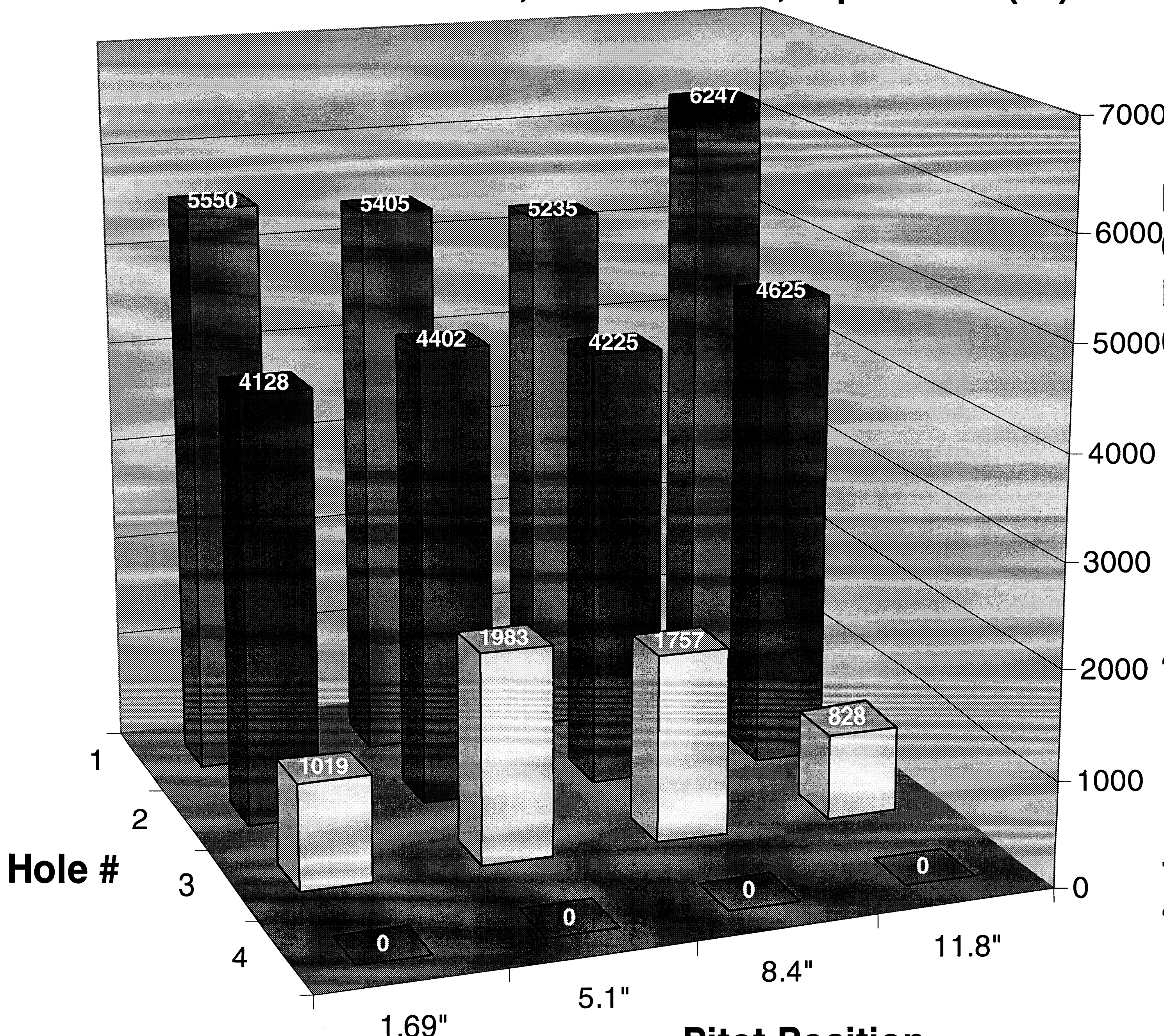



**Hole Orientation**

**3990 SCFM, 99.8% of Design -1.7% < 4058 SCFM**

**Min. = 0 SFPM Max. = 2910 SFPM**

## 16.25 x 13.5 Outlet, Low Position, Equal-Area (#8)

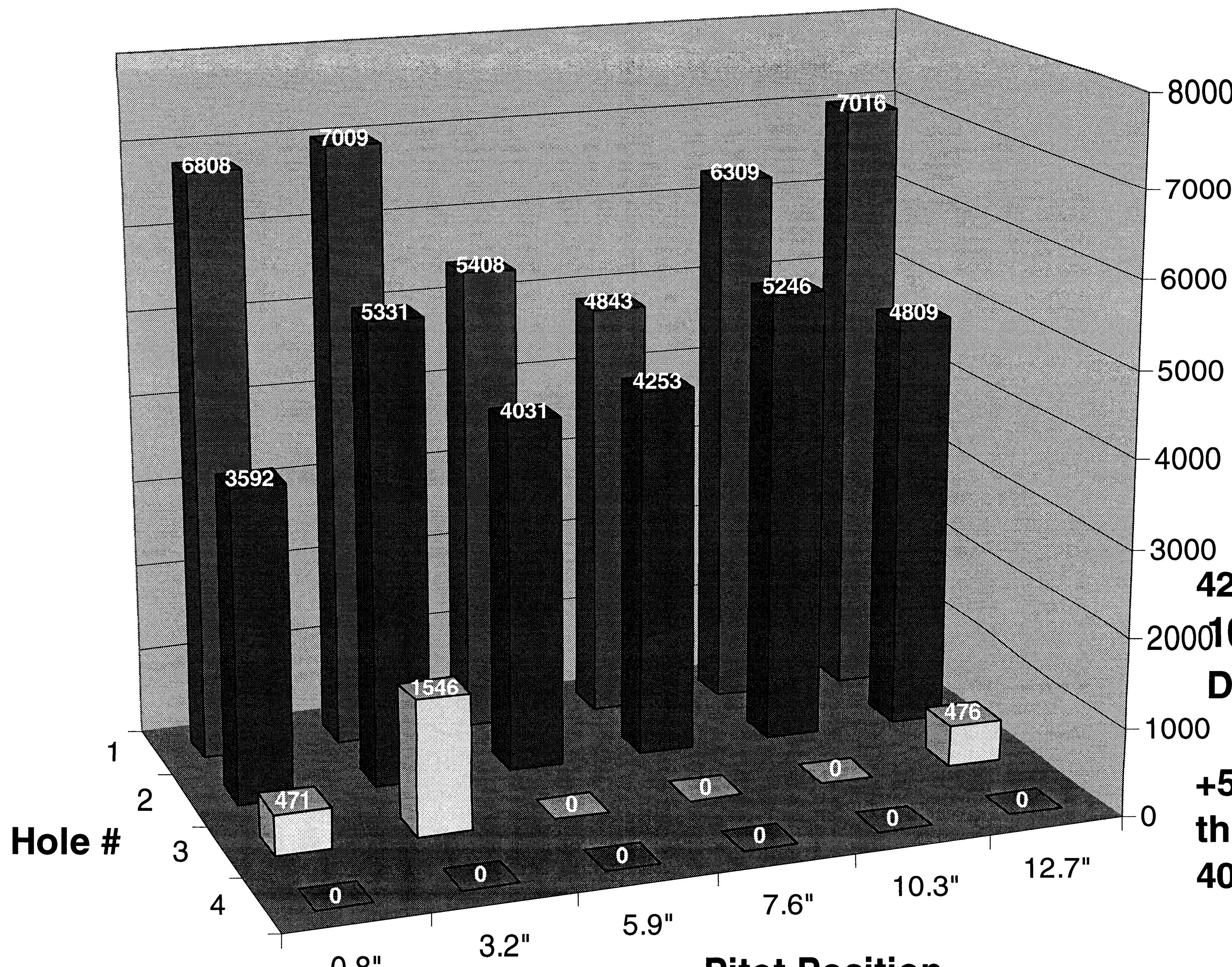



Min.= 0 SFPM
Max. = 6247 SFPM

4322 SCFM, 108.1% of Design

+6.5% > than 4058 SCFM

# 16.25 x 13.5 Oulet, Low Position, Log-Tchebycheff (#7) Not Qualified

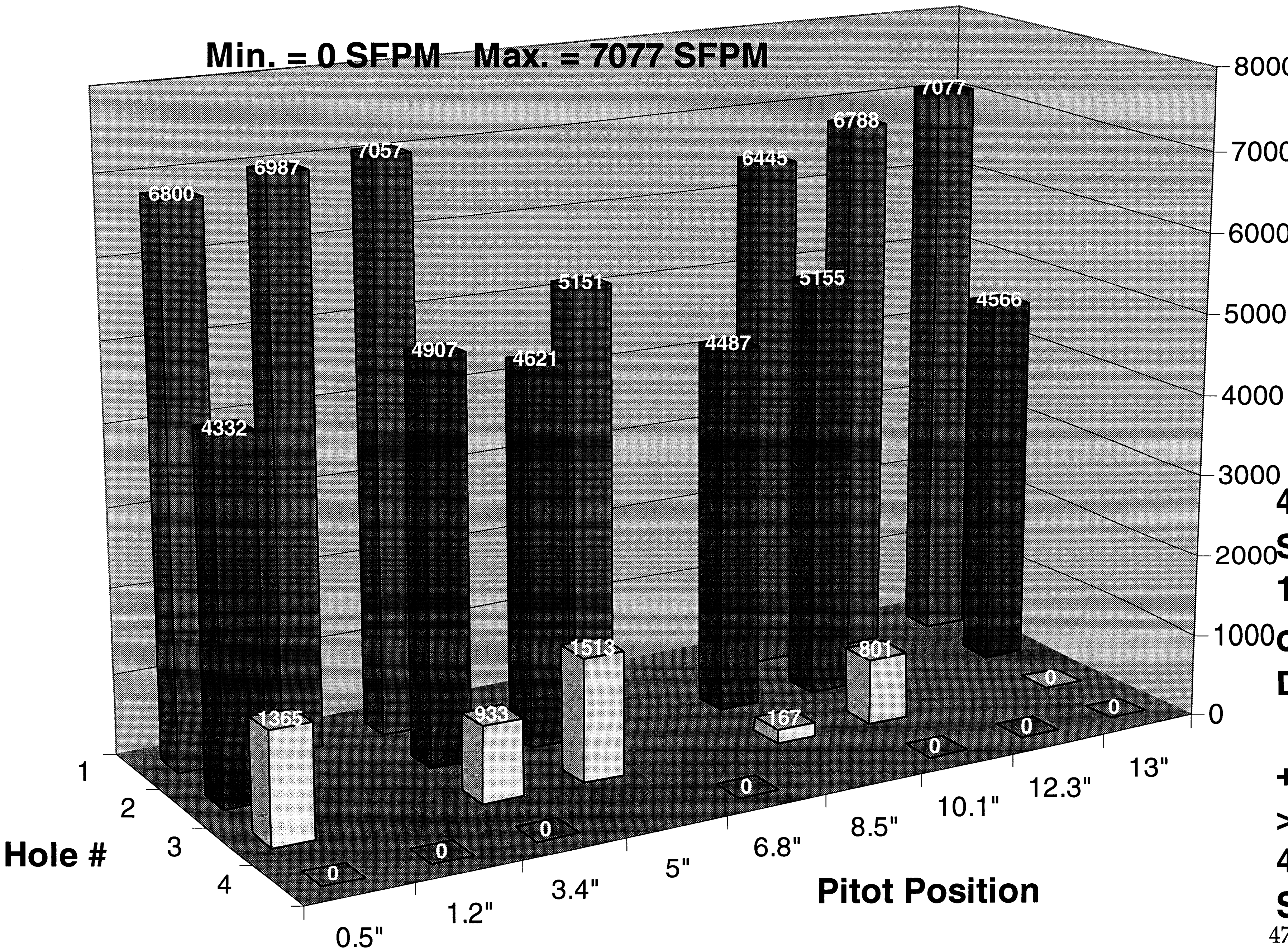



Min. = 0 SFPM
Max. = 7016 SFPM

4261 SCFM, 106.5% of Design

+5.0% > than 4058 SCFM

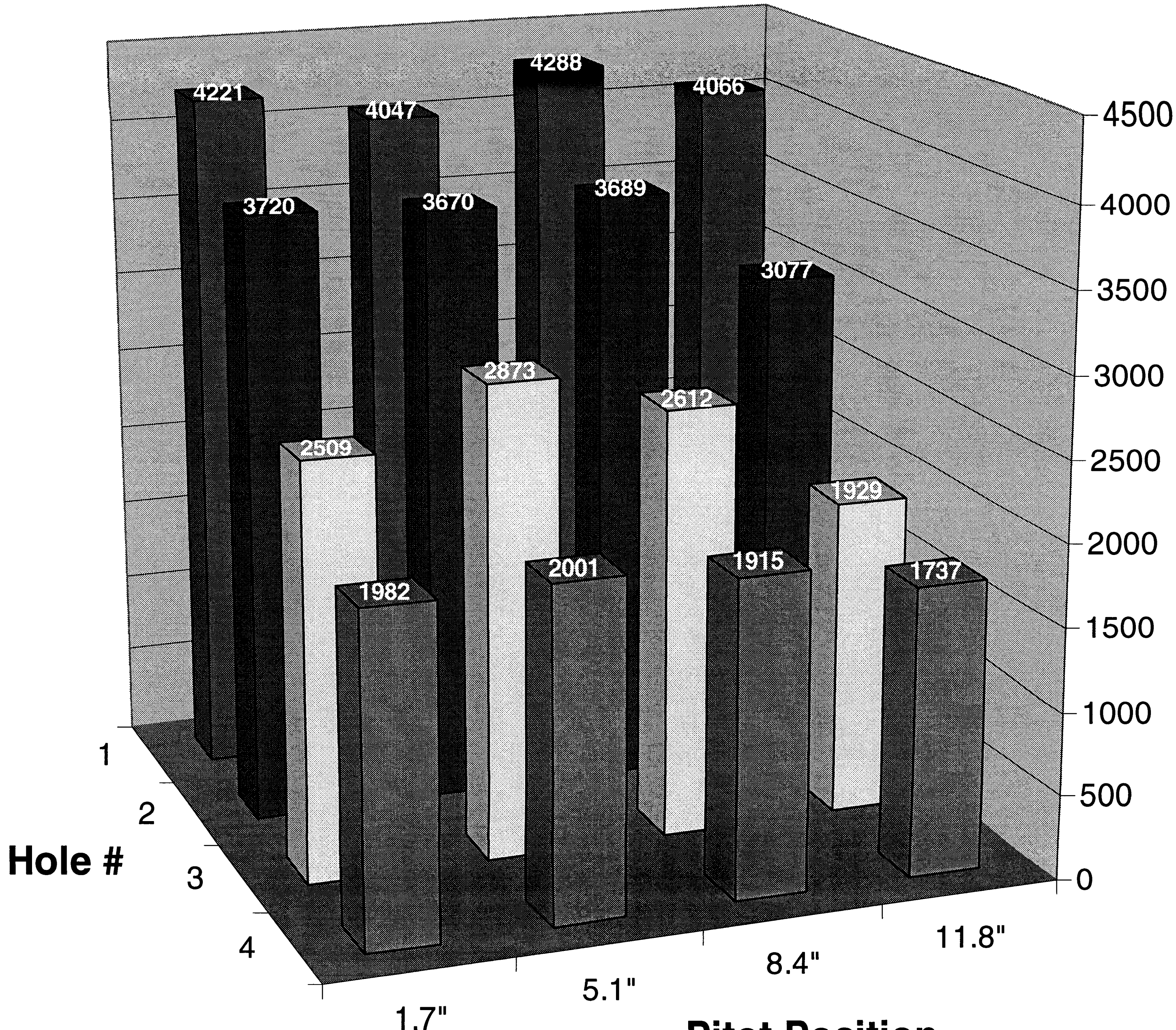
# 16.25 x 13.5 Outlet, Low Position, Log-Linear (#7) Not Qualified




**4516 SCFM, 112.9% of Design**

**+11.3% > than 4058 SCFM**

## 16.25 x 13.5 Outlet, High Position, Equal Area (#10)

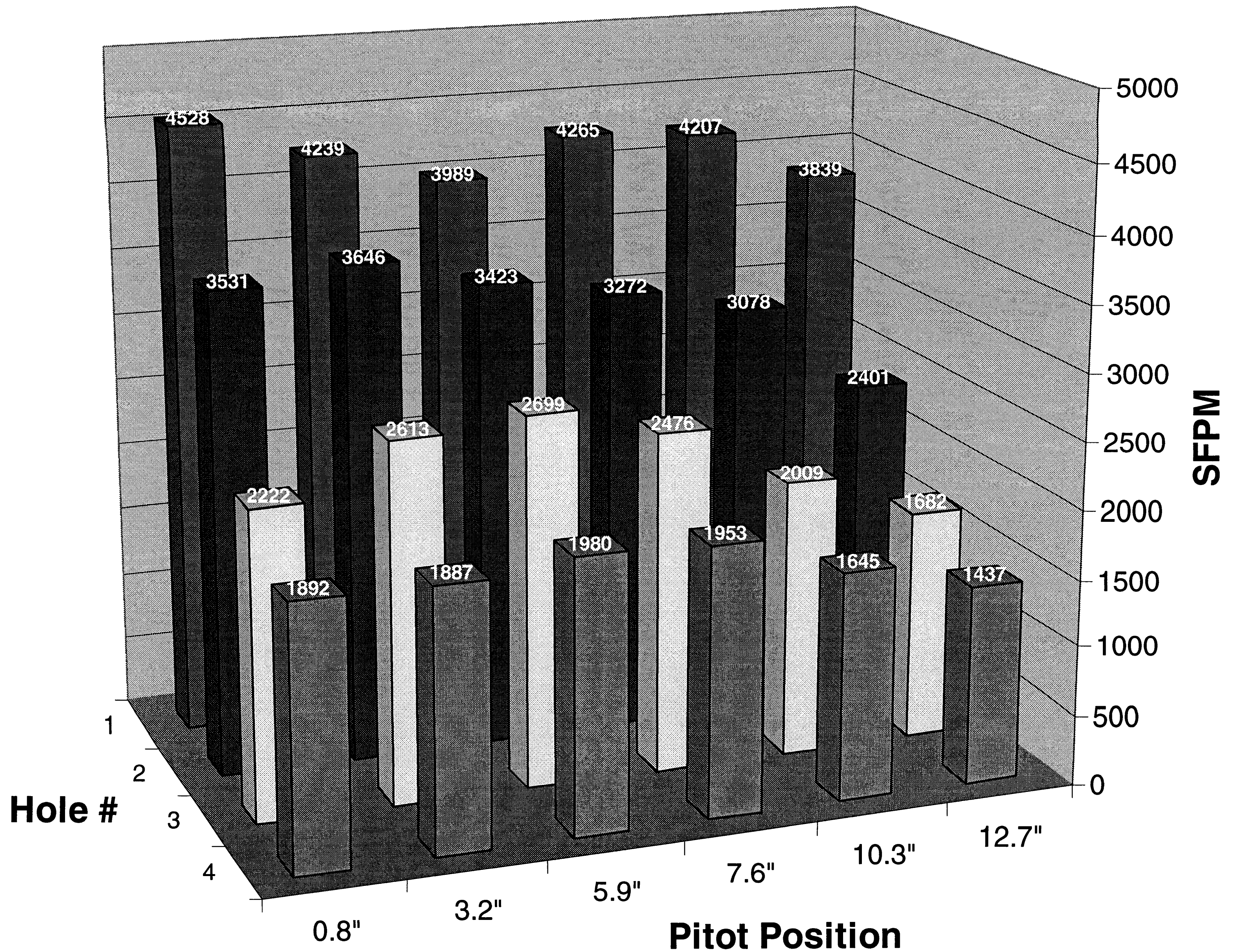



**Min. = 1737 SFPM**
**Max. = 4288 SFPM**

**4604 SCFM, 115.1% of Design**

**+13.5% > than 4058 SCFM**

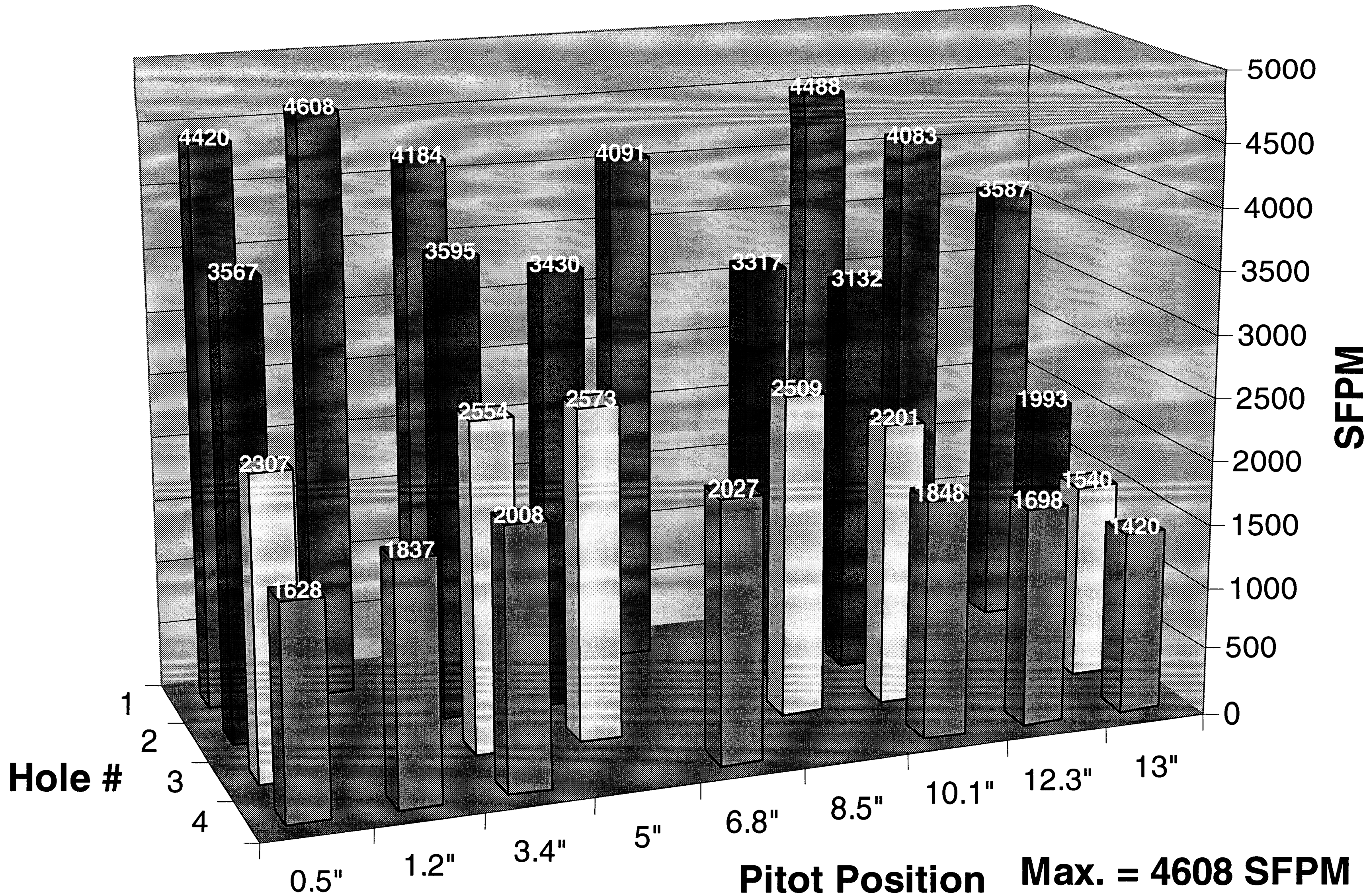
# 16.25 x 13.5 Outlet, High Position, Log-Tchebycheff (#9)




**4376 SCFM, 109.4% of Design. +7.8% > than 4058 SCFM**

**Min. = 1437 SFPM Max. = 4528 SFPM**

# 16.25 x 13.5 Outlet, High Position, Log-Linear (#9)

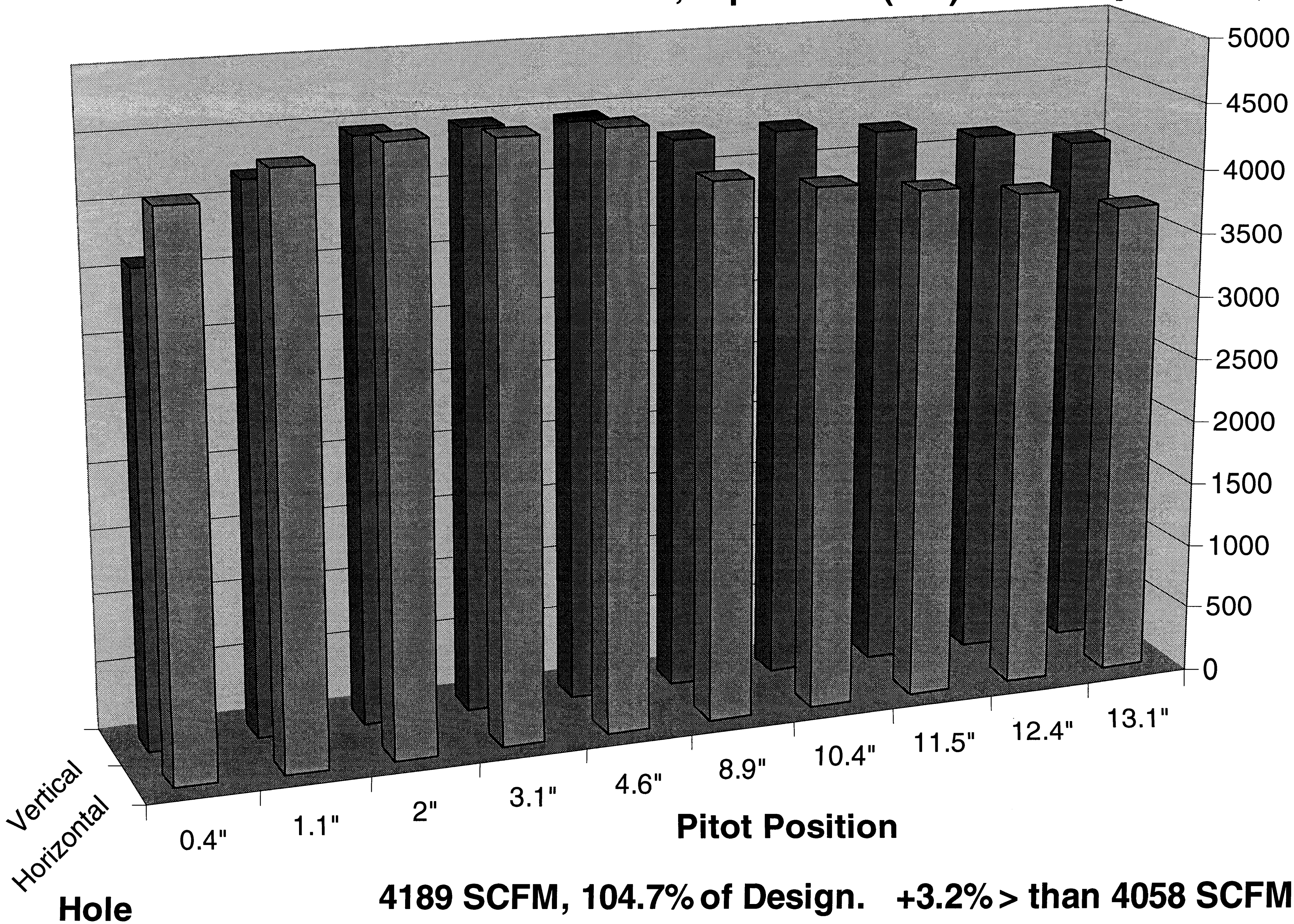



**Max. = 4608 SFPM**

**Min. = 1420 SFPM**

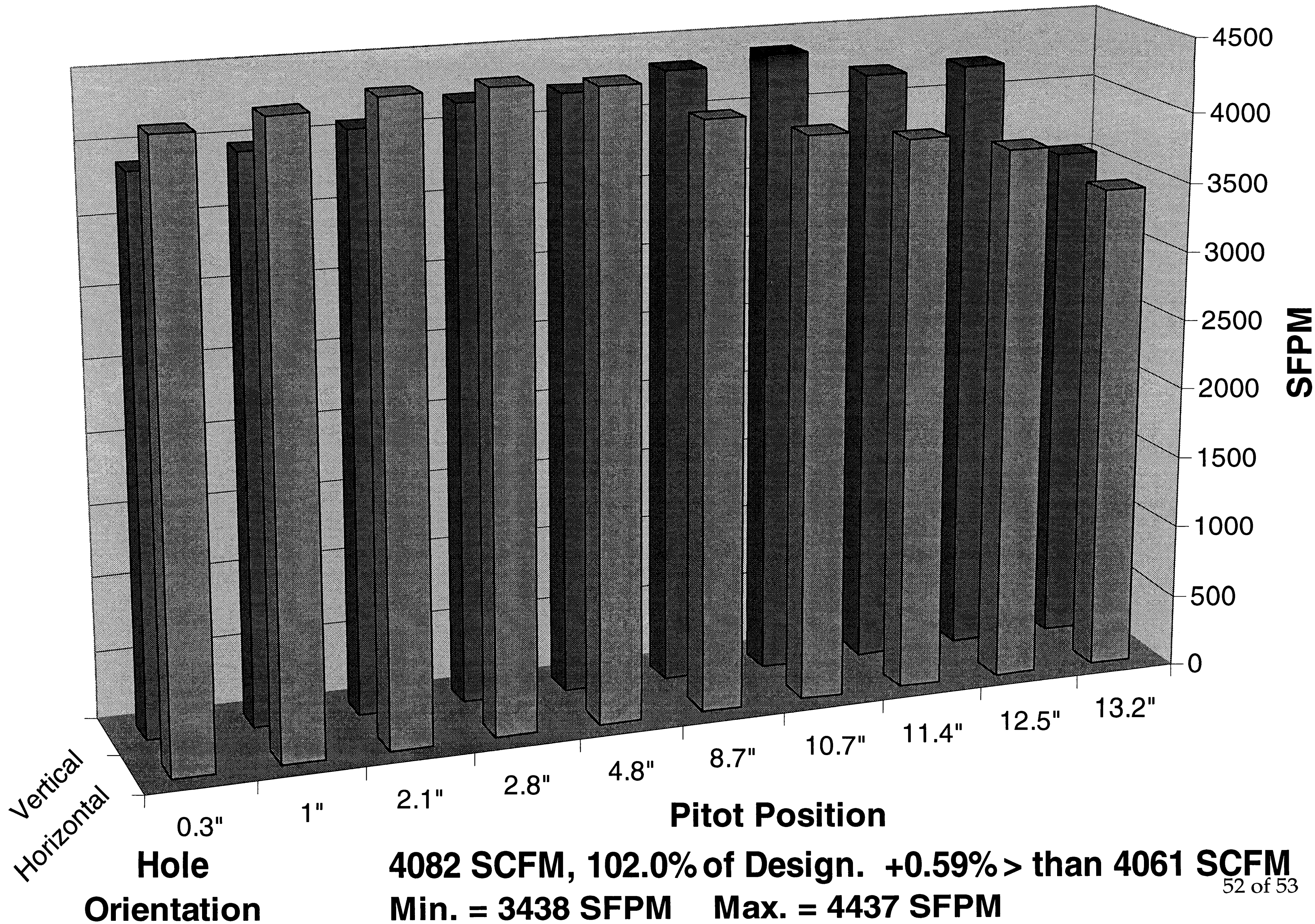
**4436 SCFM, 110.9 % of Design**
**+9.3% > than 4058 SCFM**

# 13.5" Round Outlet, Equal Area (#12)




**4189 SCFM, 104.7% of Design. +3.2% > than 4058 SCFM**
**Min. = 3611 SFPM, Max. = 4587 SFPM**

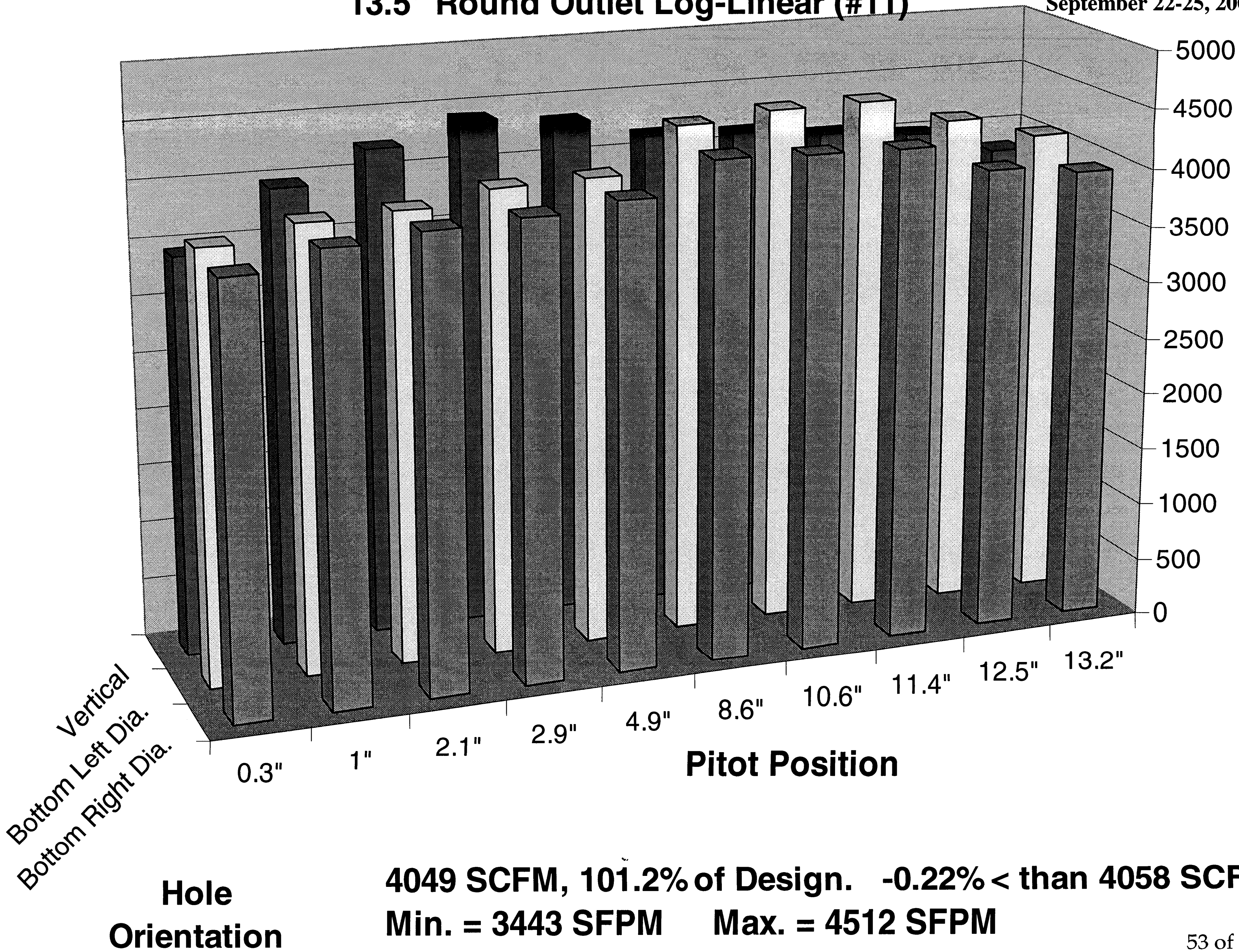
## 13.5" Round Outlet, Log-Tchebycheff (#12)




**4082 SCFM, 102.0% of Design. +0.59% > than 4061 SCFM**

**Min. = 3438 SFPM Max. = 4437 SFPM**

# 13.5" Round Outlet Log-Linear (#11)




**4049 SCFM, 101.2% of Design. -0.22% < than 4058 SCFM**

**Min. = 3443 SFPM Max. = 4512 SFPM**